Determination of the

Refraction of the Eye

With the

Ophthalmoscope.

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DETERMINATION

OF THE

REFRACTION OF THE EYE

BY MEANS OF THE

OPHTHALMOSCOPE.

BY

EDWARD G. LORING, M.D.,
NEW YORK.

FROM ADVANCED SHEETS ON THE OPHTHALMOSCOPE.

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DETERMINATION OF THE REFRACTION OF THE EYE BY MEANS OF THE OPHTHALMOSCOPE.

EDWARD G. LORING, M.D., NEW YORK.

If the ophthalmoscope was one of the most brilliant inventions ever known to medical science, it was certainly, also, one of the most complete, for the very method first proposed by Helmholtz still remains by far the most beautiful, comprehensive, and truthful of all the means yet in our possession for the exploration of the bottom of the eye.

As a knowledge of this method—that by the upright image—is absolutely necessary for the determination of the optical condition of the eye, a few words as to the manner in which it should be performed in general, may be of service to the reader before proceeding to the more difficult task of determining in a given case the nature and exact degree of refraction.

The position of the patient and examiner is not without importance. The observer should sit well to the side of the patient, and on the side, of course, of the eye to be examined. If the right eye is to be examined, the patient should be directed to look slightly towards the right; if the left eye, then towards the left.

In fact, the directions are exactly opposite to those given for the inverted image, and just the contrary from what are usually laid down in the books.

This position in the examination throws the optic axis away from the median line and places the optic nerve just opposite the pupil, and allows the observer to approach very near the observed eye without bending too much over the person examined.

The observer must learn to use either eye and either hand as

occasion may require, so as to be able to examine the patient's right eye with his right, and the left with his left, holding the ophthalmoscope in the right or left hand, as the case may be.

As the examination by the upright image consists of looking directly through the pupil to the fundus beyond, the observer should bring his own eye as closely to the observed eye as is possible; for when obliged to look through a narrow opening, the nearer we bring our eye to the edges of the aperture, the wider will be the field of view of what lies beyond. Also, as a matter of course, the larger the pupil, the easier the inspection and the greater the extent of fundus seen. For this reason the first attempt of the observer should be with a dilated pupil.

For an observer to see the details of the fundus clearly with the upright image, some knowledge of the optical condition of his own eye is necessary, as well as that of the eye to be observed, and any existing fault should be corrected by the proper neutralizing glass.

The inexperienced observer, even if emmetropic and able to relax his accommodation perfectly for distant objects, is usually a little, sometimes a good deal myopic for the ophthalmoscope. This comes from the fact, that he is unable to adjust his eye for parallel rays, when looking into an eye which he knows to be only a short distance from him. He instinctively accommodates and transforms his eye for the time being from an emmetropic to a myopic eye. This must be corrected by a suitable concave glass behind the mirror.

It is better for the beginner not to waste too much time in trying to correct his myopia, either natural or acquired, too exactly; but to take such a glass as will enable him to see the fundus with ease and distinctness, and this having been attained the observer will gradually learn to discard the use of too strong a glass by gradually substituting for it a weaker one. The weaker the concave glass, consistent with perfectly clear vision, the better. If on the other hand, the observer is hypermetropic and can so relax his accommodation as to be able to use a convex glass, this should be as strong as possible, so that he may see with as little strain on his accommodation and get as large an image as can be secured.

The general direction for the movements of the patient's eye, up and down, to the right and left, are of course the same as with the inverted image, only it must be borne in mind that the positions of the objects are really as they appear and not, as with the inverted image, reversed. The macula lutea is found by following a line directly outwards from a little below the centre of the optic nerve and for a distance from its edge of a little over two of its diameters.

The observer having become so at home with the upright image that he can readily obtain a perfectly distinct view of the fundus through an undilated as well as a dilated pupil, should then, but not before, turn his attention towards what may be called some of the niceties, if not the beauties, of the art, chief among which is the ability to determine the optical condition of the eye. To do this in a satisfactory manner, the observer should have a suitable instrument.

The great aim in the construction of an ophthalmoscope should be largeness of field of view with a suitable and sufficient illumination. These requirements seem to be fulfilled best in the shape and construction of what is known now as Liebreich's smaller ophthalmoscope, which consists of the concave mirror with a central aperture first introduced by Reute, attached to a short straight handle. The mirror is usually about seven inches focal length, with a clip at the back for the necessary correcting glasses.

Unfortunately Liebreich's instruments, as made abroad, though cheap, are comparatively worthless, from the mirrors not being true, and from the annoying reflections arising from the edges of the perforation and back plate of the mirror. The whole instrument is, moreover, so flimsily constructed, as to be liable to break with the most careful handling.

For lightness, durability, freedom from reflections, and general usefulness, there are no superior instruments to those now made in New York, and notably by Mr. Hunter.

The instruments of this maker in the way of workmanship and optical accuracy are unsurpassed.

As Liebreich's instrument was not compendious enough to meet the growing requirements of ophthalmic science, the following

modification[1] of the instrument was made, the principal feature of the change being the substitution of detachable cylinders for the ordinary clip, or for the fixed Rekoss disk. In the present case but three cylinders are employed, though these might be multiplied indefinitely were there any occasion for so doing. Each cylinder is pierced for eight glasses, forming in the aggregate the following series:

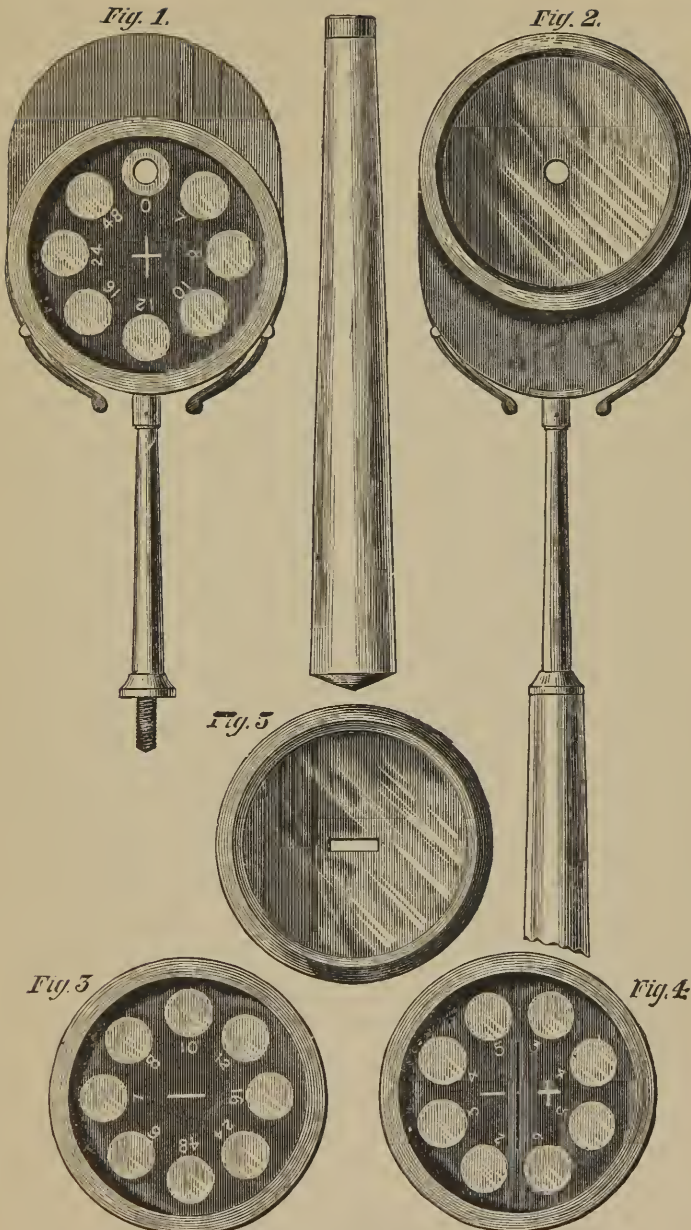
Convex....... 0, $\frac{1}{48}$, $\frac{1}{24}$, $\frac{1}{16}$, $\frac{1}{12}$, $\frac{1}{10}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$.
Concave...... $\frac{1}{48}$, $\frac{1}{24}$, $\frac{1}{16}$, $\frac{1}{12}$, $\frac{1}{10}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$.

Thus we have a series of glasses extending, with but comparatively slight differences in focal value, from convex 1-48 to 1-3, and from concave 1-48 to 1-2.

The manner in which the glasses are divided among the cylinders will be readily understood from the accompanying drawings. The first cylinder is made up entirely of convex glasses, by means of which all ordinary degrees of hypermetropia can with sufficient exactness be determined. One hole (0) is left vacant to represent emmetropia, without the necessity of removing the cylinder, and for examination by the inverted image without an eye-piece; should, however, the latter be desired, the observer has a large selection at his command. The second cylinder contains the concaves of moderate focal power, and the third is composed of the high numbers, both positive and negative. These strong numbers are designed for the determination of the highest degrees of errors of refraction and for the measurement of the inequalities of the fundus, such as excavations and elevations of the optic nerve, projections of tumors, retinal detachments, membranes in the vitreous, et cetera. With the stronger convex, such as 1-3, opacities of the cornea and lens can be viewed under considerable enlargement.

The cylinders fit into a cell at the back of the instrument and are held firmly in their place by means of the two small springs shown in the engraving, which, projecting into a groove in the side of the cylinders, prevent these from falling out, yet do not interfere with their rotation. In turning, the centre of the glass comes opposite the centre of the hole in the mirror.

[1] Trans. American Ophth. Soc., July, 1869.



EXPLANATION OF DRAWING.

Fig. 1. Back of instrument with cylinder in position.
Fig. 2. Front view of instrument.
Figs. 3 and 4. Remaining cylinders detached.
Fig. 5. Astigmatic optometer and mirror.

Great care was taken to have the mirror, which is concave, seven inches' focal distance, ground exceedingly thin—as thin almost as a metal mirror—while all the surrounding brass work is so beveled away that as little impediment as possible is offered to the passage of the rays, thus rendering the image perfectly distinct, and I think unusually brilliant.

The mirror being contained in a separate case of its own is made detachable from the rest of the instrument, which can then be used as an optometer, the patient himself revolving the cylinder till the suitable glass is obtained. As the perforation through which the patient looks when the mirror is removed is equal to the diameter of the glass (three lines), and is much larger than the normal pupil, the peripheral rays are not cut off, which is usually a source of error when smaller diaphragms are used.

The handle of the instrument has purposely been made unusually long, so that the observer's hand shall not interfere with an easy and close proximity to the observed eye, which is a great advantage in examination by the upright image.

The instrument, the three cylinders, and a convex two and one-half inch lens for examination by the inverted image, are all contained in a small pocket-case, measuring four and three-quarter inches by two and one-half square by three-quarters thick.

The common weak mirror, consisting of three plates of plane glass, can be easily fitted to the instrument should it be desired.

The second mirror was originally designed for a stenopæic slit to be used with the instrument when employed as an optometer for the determination of astigmatism. It consisted of a thin plate with a slit in it, whose length was equal to the diameter of the perforations in the cylinder. This was mounted like the mirror, and made to fit in the mirror cell in which it revolved, so as to allow the slit to correspond with any given meridian of the cornea. The meridian once determined, the patient turned the cylinder till the suitable glass was obtained. This plate was subsequently made with a polished surface in front, and then was made to serve also as a mirror for determining, by means of the ophthalmoscope, the amount of astigmatism in the principal meridians of the eye. Practically, however, this is of little use, as the simple round perforation answers every purpose.

This instrument can be obtained from its maker, H. W. Hunter, optician, 1132 Broadway, New York City. Price $40.

As these instruments were more elaborate than was required for ordinary ophthalmoscopic work, and consequently expensive, a simpler form was designed for the use of students and general practitioners, consisting of a single disk, having at first perforations for nine glasses, which were afterwards increased to twelve and sixteen.

The series for that containing twelve glasses (Fig. 6) is as follows:

$$0, + \tfrac{1}{36}, \tfrac{1}{18}, \tfrac{1}{12}, \tfrac{1}{8}, \tfrac{1}{5}, \tfrac{1}{3}.$$
$$- \tfrac{1}{36}, \tfrac{1}{18}, \tfrac{1}{12}, \tfrac{1}{8}, \tfrac{1}{5}, \tfrac{1}{3}.$$

That for sixteen glasses (Fig. 7) is:

$$0, + \tfrac{1}{48}, \tfrac{1}{24}, \tfrac{1}{16}, \tfrac{1}{12}, \tfrac{1}{8}, \tfrac{1}{6}, \tfrac{1}{4}.$$
$$- \tfrac{1}{48}, \tfrac{1}{24}, \tfrac{1}{12}, \tfrac{1}{8}, \tfrac{1}{6}, \tfrac{1}{4}, \tfrac{1}{2}.$$

A supplementary clip, if desired, can be fastened to the back, containing a negative and positive glass, as shown by the dotted lines in the drawings, which are full size. The strength of these glasses in the clip can be arranged to suit the requirements of each individual, and as they can be readily brought into position over the disk which rotates beneath, they can be used either to correct an optical defect in the observer's eye, or for the purposes of obtaining, in conjunction with the disk, a large combination of both positive and negative focal values.

These instruments are in every way as durable and as optically perfect as the larger ones. At the same time they are sufficiently comprehensive for all ordinary use, even without the clip; with it, they fulfil even the most exacting requirements of ophthalmoscopy.

The comparatively low price at which they are sold,[1] and the small compass in which they are contained, are certainly recommendations in their favor. The price of the instrument containing twelve glasses is $14.00; that sixteen, $18.00.

At the meeting of the American Ophthalmological Society for 1873, Dr. Knapp presented a modification[2] of the Rekoss system,

[1] H. W. Hunter, optician, 1132 Broadway.

[2] Transact. American Ophthal. Soc., July, 1873.

Fig. 6.

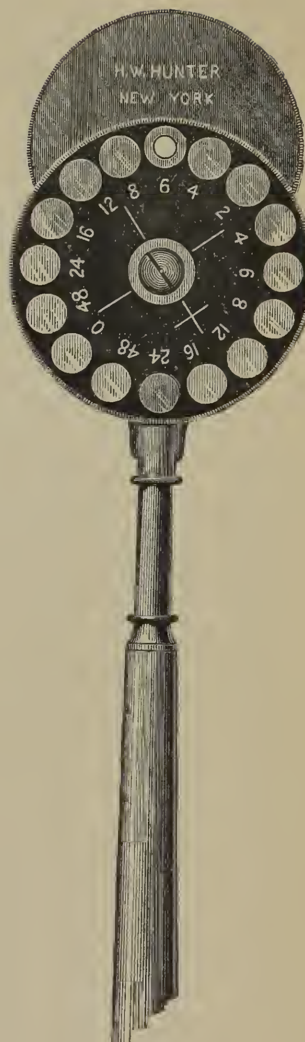


Fig. 7.

which consists of two undetachable but revolving disks, one of which contains concave, the other convex glasses. These are superimposed in such a manner that they rotate past each other, so that the focal value of each glass can be lessened to a greater or less degree (but not increased) by adding to it the various neutralizing glasses of the other disk. As there are twelve glasses in each disk, the focal value between the glasses is in itself small, but this can be made much smaller by the use of the other disk. But the presence of both disks at the same time necessitates (unless, indeed, one is on each occasion turned to zero) an elaborate calculation before the real focal value of the combination before the observer's eye can be determined.

To facilitate this, a table has been prepared by Dr. Knapp, and published in the *Archives of Ophthalmology and Otology*, Vol. III., No. 2, 1874.

Perhaps a simpler form of obtaining the many combinations afforded by the use of two disks was that employed some time ago by the writer. This consisted of two disks placed one over the other. The brass rim of the lower disk projected just enough beyond the edge of the upper to allow the former to be rotated without affecting the latter, which had an independent movement of its own. By arranging the glasses so that each disk shall contain concave as well as convex, the focal power of each glass can be increased as well as diminished, which is not the case where one disk contains, as in Dr. Knapp's instrument, all the convex, and the other all the concave lenses. These instruments are, however, of little or no practical value, as the calculation in case of all the weaker numbers, and even of the moderately strong ones, can only be carried out, even by an adept, on paper, or by a prepared table, and the result, when obtained, gives a focal interval of so small a degree as in most cases to be entirely inappreciable even to the most proficient expert. In order to use any of the numbers that more commonly occur without going into this calculation, one disk must be always turned to zero, while the required number is sought by revolving the other.

Dr. Knapp's instrument, like that of Wecker's,[1] has the advan-

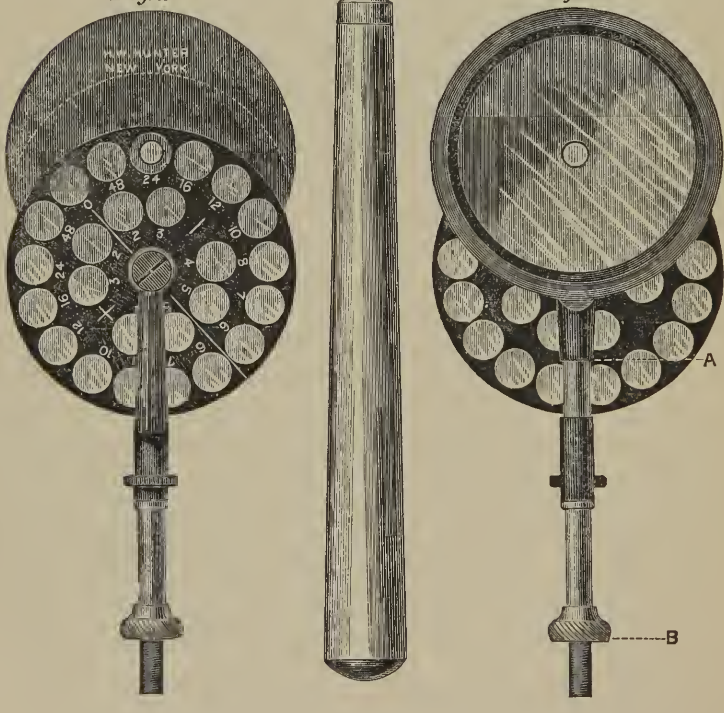
[1] For a description and drawing of this ophthalmoscope see Klin. Monatsblätter, Zehender, Sept., 1873.

tage of being complete in itself, and free from the disadvantage of having detached cylinders.

To obtain this advantage, and at the same time to keep the primitive simplicity of my old instrument, the detachable cylinders have, in the modification [1] presented below, been replaced by a single stationary disk which is only one and a half inches in diameter, and in which the glasses are arranged in two concentric circles. The manner in which this is done will be seen from the figure. The disk contains 25 perforations, forming, in the aggregate, the following series:

Convex..... 0, $\frac{1}{48}$, $\frac{1}{24}$, $\frac{1}{16}$, $\frac{1}{12}$, $\frac{1}{10}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$.
Concave.... $\frac{1}{48}$, $\frac{1}{24}$, $\frac{1}{16}$, $\frac{1}{12}$, $\frac{1}{10}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$.

Fig. 1 *Fig. 2*



[1] American Journal of Medical Sciences, January, 1874.

The intervals between the focal lengths of these glasses are small enough to fulfil every requirement in ophthalmoscopy, without the perplexing resort of adding and subtracting vulgar fractions with comparatively high denominators. If required, however, it is very easy to vary the focal interval in all the stronger, and in many of the moderately strong glasses, that is, from $\frac{1}{2}$ to $\frac{1}{10}$. This is done by the observer simply withdrawing his head half an inch from the ordinary place of examination. If, for example, it is found that in the usual place $-\frac{1}{2}$ in a given case is too strong, the head has only to be withdrawn one-half inch, and the glass has then the effect of $\frac{1}{2\frac{1}{2}}$. With $\frac{1}{3}$ it becomes $\frac{1}{3\frac{1}{2}}$, and so on through the series. So, too, with the convex glasses; only here the glasses increase in strength as we withdraw the head. Thus if we find that $+\frac{1}{3}$ is not quite strong enough in a given case, we have only to withdraw our head half an inch and the glass has the same effect as $\frac{1}{2\frac{1}{2}}$ would have had if the head had not been moved. Thus, with little or no inconvenience, a large number of additional focal values, with small intervals of refraction, can be obtained. The disk is divided perpendicularly into two equal parts, one of which contains the convex, the other the concave. In each half the weaker and more commonly occurring glasses are set in the outer semicircle, while the stronger ones are put in the inner one.

The outer or inner circle can be rapidly brought into position by simply sliding the disk upwards or downwards on the handle by means of the thumb of the hand which holds the instrument, and this can be done if desirable without removing it from the eye. By this simple contrivance all the necessary glasses are contained in a single stationary but revolving disk, and they can be brought into position with the least possible delay or inconvenience. In order to clean the glasses, which need only be done very rarely, it is only necessary to unscrew the handle near the mirror, and the disk can then be readily slipped off the handle and both surfaces of the glasses thus exposed.

The mirror, being contained in a separate cell, is made detachable, so that a weak light mirror can be substituted, or the instrument be used, when the mirror is removed, as an optometer.

While every effort has been made to make the parts necessary

for optical purposes as delicate as possible, the instrument itself has been purposely made sufficiently strong to withstand even more than ordinary wear and tear. It can be had of the maker, H. W. Hunter, 1132 Broadway, New York. The price of the instrument is $30.

Dr. Knapp,[1] keeping precisely the same series of glasses as used by the writer in his first instrument, arranged these in a single circle round the periphery as had Wecker a short time previously.[2]

Dr. Knapp's small instrument, like Wecker's, is covered in to prevent the soiling of the glasses. This cover is separate from the instrument, and is maintained in its position by a screw at the back.

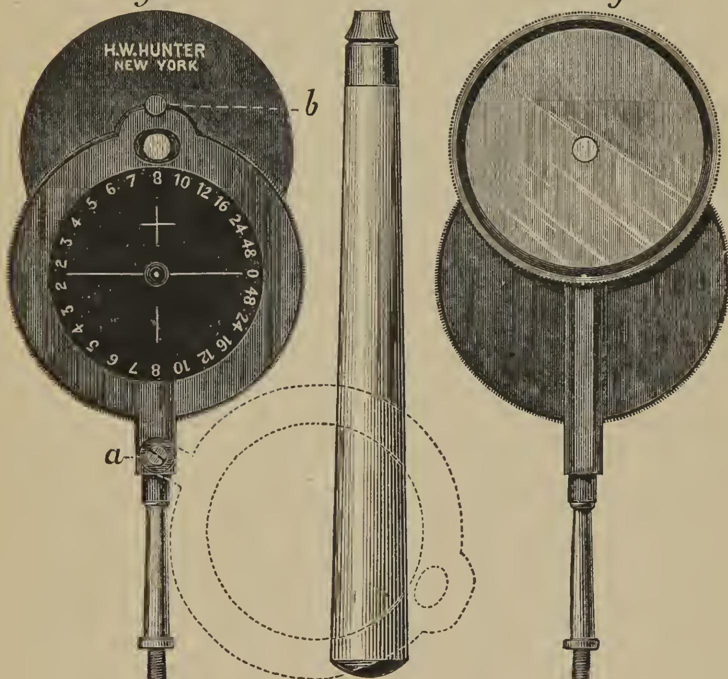
As it is considered by some an improvement to have the glasses covered, the following instrument was devised, which it was hoped would fulfil this requirement, and at the same time leave the numbers of the glasses open to inspection so that their relative position could be told at a glance, and the required number turned to at once. This object was obtained by having the cover in the shape of a thin flat ring which swings round a pivot, as seen in the drawing at the point *a*. The cover, when closed, is held firmly in position by sliding with a little pressure beneath the pivot *b*. The cover is made just wide enough to protect the glasses, but leaves the central parts of the disk uncovered. Around the circumference of this central space the numbers are engraved. An aperture of an oval shape, so as to avoid lateral reflections, is left in the ring opposite the hole in the mirror, and immediately behind the glasses, as they come into position. The entire length of the optical canal from the anterior surface of the mirror to the

1 Archives Ophth. and Otology, Vol. III., No. 2, 1874.

2 This, of course, necessitated a great reduction of the diameter of the glass. The writer had himself, several years ago (1868), a disk made in which the diameter of the glass measured only 3½ mm. The cost of the instrument was so great at that time as to debar its use from all except an occasional enthusiast. Since that time the facilities for accurate, and at the same time more reasonable, optical work have increased in this country, and ophthalmoscopes with small glasses are in high favor. So far as the mere optical picture is concerned I prefer those with the larger glasses. It is, perhaps, a convenience to have the instrument complete in itself, and as a combination of both advantages I know of no better instruments than the cheaper ones made by Mr. Hunter.

posterior one of the glass is only $2\frac{1}{2}$ mm. The disk has 25 perforations, with the same series of glasses as in the former instruments, and their manner of division and general arrangement is the same, as will be seen from the drawing. A spring is countersunk on the upper part of the handle which bears on the disk so

Fig. 1 *Fig. 2*



as to keep it firm, and serves, at the same time, to centre each glass by dropping into a small perforation beneath it. The disk can be rotated either with or against the sun, and can, if occasion require, be turned by means of the forefinger without removing the instrument from the eye. This is, however, of little or no practical importance, as the observer is apt to become confused; and the patient unduly fatigued from the continuous glare.

The disk moves on a central pivot flush with its surface. When, therefore, it is necessary to clean the glasses the cover is simply made to swing round the pivot at *a*, to the required amount, when

the disk, by turning over the instrument, drops out of itself. As the cover is not detachable, and as the pivot at *a* is a fixed peg with a washer, there are no loose screws about the instrument. The dotted line shows the manner of uncovering the glasses. The price of the instrument, as made by Mr. Hunter, is $30.

DETERMINATION OF THE OPTICAL CONDITION OF THE EYE BY THE OPHTHALMOSCOPE.

Beautiful and comprehensive as the upright image is, as a whole, it has one particular advantage above all others, which, as Helmholtz himself pointed out, is "the ability to determine the optical condition of the eye, independent of its visual power, or the statements of the person examined."

Since Helmholtz first pointed out this fact in 1851, Ed. Jaeger, Donders, and others have written upon the subject, but it is to Mauthner, in his admirable work on the ophthalmoscope, that we are indebted for the most exhaustive treatise which exists on this important branch of ophthalmoscopy.

Any ophthalmoscope which is provided with an apparatus at the back for holding the necessary glasses may be used. Here it is that the modern instruments have such an advantage over the older—so much so, indeed, that little can be done in this important branch without one.

The kind of mirror, too, is rather a matter of preference than necessity; some examiners preferring a plane, others a concave silvered one. For the simple determination of errors of refraction, I must say that I have a decided preference for the latter wherever it is not directly contra-indicated by a dread of light on the part of the patient. There are, it is true, cases where the iris is unusually responsive to light, where it is necessary to use the weak illumination, and even here the difficulty can be usually met by reducing the volume of light employed.

As the very word refraction implies the true optical value of an eye independent of its accommodation, it follows that this condition can only be ascertained when the eye examined is in a state of rest. Further, that it is indispensable that the observer should be aware of the exact state of refraction and accommodation of his own eye, before he can estimate that of another.

Perfect relaxation of the accommodation in the observed eye can of course be obtained by atropia, no matter what the nature of the refraction is. But usually, sufficient relaxation can be secured in emmetropia by causing the patient to look into the distance, and as much as possible into vacancy, which is induced somewhat by having the walls of the ophthalmoscopic room painted black. For a myope it will only be necessary that he should look at some object which is at a greater distance than his far point. The ability and disability which hypermetropes have in relaxing their accommodation will better be considered a little later under its special heading.

As far as the observer is concerned, it can be laid down as a rule, at least for beginners, that the nearer the refraction of his eye approaches emmetropia, and the more completely he can relax his accommodation, the better. This ability to relax the accommodation varies with different people, some acquiring the power completely, others only partially. Practice here, as elsewhere, increases the ability. If the observer is emmetropic, one of the best methods of acquiring this control over the accommodation is to take a convex glass of a moderate power, say $\frac{1}{8}$, and ascertain the farthest point at which fine type can be read with perfect distinctness through the glass, the other eye being closed, or better still, opened but excluded from the visual act by a screen. Under this condition there is a tendency for the visual axes to assume a parallel position, and with it that perfect state of rest usual to the eye when looking at the most distant objects. If the object can be moved in this case to a distance of eight inches, it is proof positive that the accommodation is entirely relaxed, since, as the object viewed is situated at the principal focus of the glass, only parallel rays can enter the eye, and such rays can only be brought to a focus on the retina of an emmetropic eye when it is in a state of perfect rest. This experiment should be repeated

with glasses of various strengths till the ability is acquired of always seeing the test object at the focal distance of the glass used. This once acquired, a little further practice with the ophthalmoscope will also enable the observer to relax his accommodation during the examination.

If, however, the object viewed cannot be removed from the eye to a distance equal to the focal length of the glass, then it is evident that the accommodation is not entirely relaxed. If, for example, convex $\frac{1}{8}$ be used, and the object, instead of being seen distinctly at eight inches, can only be so seen at six, then it is evident that some accommodation is still going on, and the exact amount of this will be equal to the difference between $\frac{1}{6}$ and $\frac{1}{8} = \frac{1}{24}$. Continued practice may soon enable the observer to overcome this involuntary contraction of the accommodation. Sometimes, however, in spite of all his efforts, it still remains, but he soon finds that the amount used is always the same. This, then, represents the optical condition of his eye. If, for example, he finds that the amount of accommodation which he still uses is $\frac{1}{16}$ or $\frac{1}{12}$, his eye is then, practically speaking, no longer emmetropic, but myopic, equal in fact to $\frac{1}{16}$ or $\frac{1}{12}$, as the case may be. Consequently, he must use a concave $\frac{1}{16}$ or $\frac{1}{12}$, in order to see clearly a near object, the rays from which, however, enter his eye as parallel. Having thus ascertained the optical condition of his eye in its greatest state of rest, he should, having selected some one whose eye has been proved to be emmetropic, practise with the ophthalmoscope through the glass which he has previously found neutralizes the amount of accommodation which he involuntary employs.

As a rule, then, the weakest concave glass through which the fundus of an emmetropic eye can be distinctly seen, should be taken as the criterion on which the emmetropic observer, who cannot entirely relax his accommodation, should base his estimate of refraction.

If the observer is ametropic, the simplest way for him is to reduce his ametropia by the suitable glass. More, however, in regard to this matter, will be found later under its appropriate heading.

It is of course very essential, for an accurate determination of

the refraction, to have some object point in the eye examined which shall be fine enough, not only to let us judge when we see, but when we are seeing with the most perfect sharpness.

The most conspicuous object, and one for which we at first instinctively look, is the papilla, but this should never be chosen, as it very frequently is, however, as an object on which to found our observations, for the disk often protrudes, sometimes to a considerable degree, above the general plane of the rest of the retina,[1] and would thus frequently lead to the supposition that an eye was hypermetropic, sometimes markedly so, which was in reality emmetropic or even myopic. An eye lately examined by the writer was, for example, hypermetropic one-fortieth at the disk, but myopic one-eighteenth in the region of the macula. The main trunks of the central artery, besides being often on an advanced plane, at the nerve entrance, are in themselves seen under too great an enlargement to admit of nice discrimination in focal adjustment. There are, however, some very fine vessels which always leave the edge of the nerve, running out horizontally on both sides. These are admirably adapted for the purpose, when viewed at a little distance from the disk, especially towards the inner side; the best of all objects, however, at least for those who are skilful in this kind of examination, is the choroidal epithelium in the neighborhood of the macula, though the advantages which this region offers are more than counterbalanced by the difficulties which attend its examination.

The observer having found out the exact optical condition of his own eye, it remains for him, first to ascertain the nature of the refraction of the eye under examination, and then, if ametropic, to determine the exact degree of the anomaly.

If the observer is emmetropic, and relaxes his accommodation entirely, he knows that his eye is adjusted for parallel rays only. Now the only kind of eye from which rays emerge parallel, is an emmetropic eye, consequently, if the fundus of the examined is focussed sharply on the observer's retina, the rays which enter his eye must be parallel, and the eye observed must be emmetropic.

[1] Compare Schweigger's Vorlesungen, Taf. 1, figs. 1, 2.

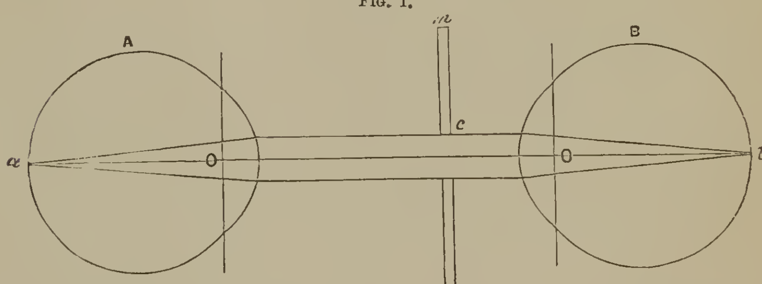
If, in a given case, the observer finds that he does not gain a clear view of the eye examined, when his own eye is in a state of rest, but that it becomes clear by using his accommodation, he then knows that the observed eye must be hypermetropic, since his own eye under tension of the accommodation is no longer adjusted for parallel, but for divergent rays, and there is no eye but a hypermetropic eye from which divergent rays can possibly come.

If the observer finds, however, that he can get no clear view of the fundus, either by relaxing or calling forth his accommodation, he knows that the rays coming from the observed eye cannot be either parallel or divergent, consequently they must be convergent, and the eye examined myopic.

Having thus ascertained, in a general way, the *nature* of the optical condition present, the next step is to determine the exact degree of the refraction. The method for doing this will be embodied, for the sake of convenience and brevity, in the following propositions, it being presupposed in all cases that the examined eye is in a state of rest as it usually is under the ophthalmoscope.

Proposition I. *For an emmetropic eye to determine that the observed eye is emmetropic.*—Let *A* (Fig. 1) be the observed eye

Fig. 1.

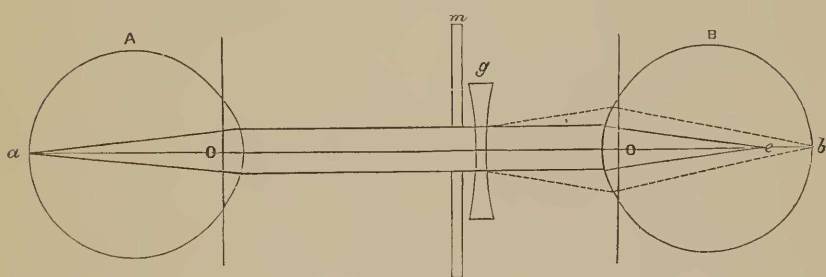


illuminated by the ophthalmoscopic mirror *m*. Since the eye is emmetropic, and in a state of rest, rays radiating from an illuminated point *a* on the retina must leave the eye as parallel, and, as such, pass through the hole of the mirror *c*. If now the observer's eye is placed behind the mirror, the rays which strike his cornea, being parallel, will, since his own eye is emmetropic

and in a state of rest, just come to a focus on his retina at the point *b*. A distinct image of the fundus will therefore be obtained, as what is true of one point is of all. As his eye is adjusted for parallel rays, and for no others, he knows the eye examined must be emmetropic; consequently, the fundus of an emmetropic eye can be distinctly seen by another emmetropic eye, without the aid of any correcting glass; provided, however, that the observer's eye is also in a state of rest.

If, however, the observer is unable to relax his accommodation entirely, it is evident that the parallel rays entering his eye must come to a focus in front of the retina, that is to say, rays coming from the point *a* (Fig. 1) will no longer come to a focus at *b*, but will unite in front of it at *e* (Fig. 2). Circles of dispersion will consequently be formed on *B's* retina, and an indistinct image of *A's* fundus will be the result.

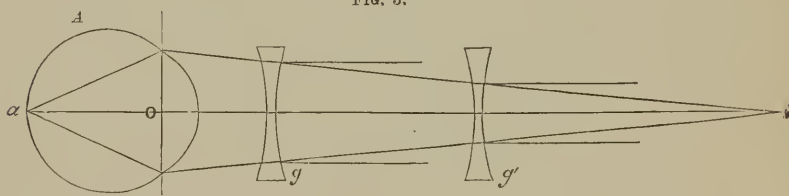
FIG. 2.



The reason of this is that *B's* eye—as has been formerly explained—though emmetropic while looking at distant objects, is as far as ophthalmoscopic examinations are concerned—since he cannot relax his accommodation—virtually myopic, and a concave glass (*g*) must be used behind the ophthalmoscope, to bring parallel rays to a focus on his retina. The weakest concave glass that will do this will then be exactly the amount that *B's* accommodation cannot be relaxed, and with it his eye will be just adapted for parallel rays; consequently, when the fundus of an eye can only be seen clearly through this glass, the eye must be emmetropic.

Proposition II. *The observer being emmetropic to determine the amount of myopia in the observed eye.*—As the observed eye is myopic, rays of light emerging from it are convergent, and will meet at a point in front of the eye, at a distance just equal to the amount of the myopia. If, for example, the myopia equals $\frac{1}{6}$, then the rays will meet at six inches in front of the nodal point. As the observer's eye, however, is emmetropic, and in a state of rest, it is accommodated, not for convergent but parallel rays, so that before the convergent rays coming from a myopic eye can be focussed on the observer's retina, they must be made parallel. This will be made clear by the following diagram (Fig. 3).

Fig. 3.



Let A be an eye myopic $\frac{1}{6}$; rays of light leaving its retina will emerge convergent, and come to a focus six inches in front of the nodal point o, at the point b. If we could place a concave lens $\frac{1}{6}$ at the nodal point o, we should neutralize the myopia, and the rays would then leave the eye as parallel, since the glass would then be just six inches from the point b, which would then represent its virtual focus. But as we cannot put the glass at the nodal point of the observed eye, we place it as near as the conditions of an ophthalmoscopic examination will permit. This distance is generally assumed to be about two inches. As the glass (g) is then two inches in front of the nodal point, the distance between it and the point b will be only four inches; consequently, it will require a concave $\frac{1}{4}$ to render the rays parallel at two inches from the eye, while it only required $\frac{1}{6}$ at the nodal point. If the glass (g') is at three inches from the nodal point, then it will be only three inches from the point b, and it will require a glass of $\frac{1}{3}$ to reduce the rays to parallel; consequently, $\frac{1}{3}$ three inches from the nodal point is equal to $\frac{1}{6}$ at it. That is to say, the glass required is just as much too strong as it is distant from

the nodal point. We must, therefore, reduce it by this quantity. In the above cases it will be $\frac{1}{4+2}=\frac{1}{6}$. $\frac{1}{3+3}=\frac{1}{6}$. From which we deduce—

For an emmetropic observer whose eye is at rest, the myopia in a given case will equal the weakest concave glass through which the fundus is seen distinctly, plus the distance of the glass from the nodal point of the observed eye.

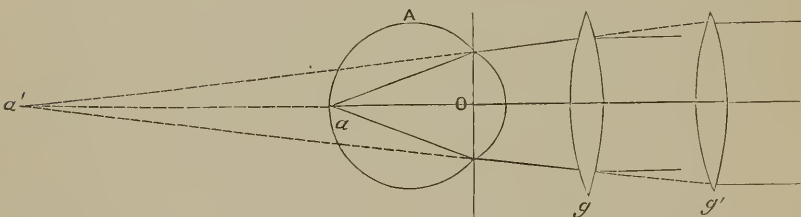
This will give the exact amount of the myopia present, but inasmuch as we usually measure degrees of ametropia by that glass which brings parallel rays to a focus on the retina, placed, not at the nodal point, but half an inch in front of it, we may for ordinary calculations omit this half inch. For example, we say a man is myopic $\frac{1}{6}$ when a concave $\frac{1}{6}$ placed one-half inch in front of his nodal point brings parallel rays to a focus on the retina; he is really, however, myopic only $\frac{1}{6\frac{1}{2}}$. So, too, with the ophthalmoscope we may neglect this half inch, and then the result will give the amount of ametropia, as it is usually expressed, in glasses.

We have taken the distance between the glass and nodal point as two inches simply as a matter of convenience, and because it represents about the distance common to those who are not adepts in this kind of examinations, especially if they use Jaeger's ophthalmoscope. With a little practice the observer can reduce this distance to one inch instead of two, and if he uses an ophthalmoscope, the mirror of which lies in the same plane with the handle, he can, with a little skill, approach so near the eye as to place the glass he looks through nearly in the position which the patient would in wearing his glasses. In this case the glass used would represent the amount of ametropia without further addition of the distance.

If the observer is unable to relax his accommodation when using the ophthalmoscope he is, as has already been explained, no longer emmetropic but virtually myopic to the amount of accommodation that he involuntarily calls forth. He has then to simply reduce his own eye to the condition of an emmetropic one by adding the suitable glass and then proceed as above.

Proposition III. *The observer being emmetropic to estimate the degree of hypermetropia in a given case.*—As the observed eye is hypermetropic, rays emerging from it will have a direction as if they came from a point situated behind the eye observed, equal to the degree of the hypermetropia. Thus the rays coming from an eye hypermetropic $\frac{1}{8}$ will emerge from it as if they came from a point eight inches behind the nodal point. For example, let A (Fig. 4) be hypermetropic $\frac{1}{8}$, then the rays, coming from the point a on the retina, will after they leave the eye diverge as if they came from a' eight inches behind the eye. As the observer's eye is emmetropic and at rest, we must render these rays parallel before they can come to a focus on his retina. If

Fig. 4.



we could place a convex glass at the nodal point of A, it would require just $\frac{1}{8}$ to make the rays parallel, inasmuch as a', which may be considered as the principal focus, is just eight inches distant, and this glass then would just equal the amount of H. If, however, we place the glass (g) behind the ophthalmoscope two inches in front of the observed eye A, then, as a' is ten inches from the glass it will only require $\frac{1}{10}$ to render the rays parallel. If the glass (g') is at four inches from the eye, then a' will be twelve inches from the glass, and it will only require $\frac{1}{12}$. Consequently the glass used is as much weaker than the hypermetropia is, as it is distant from the nodal point; we must therefore make it so much stronger, before it can represent the true degree of H in the observed eye. In the above case, $H = \frac{1}{10 - 2} = \frac{1}{8}$, $H = \frac{1}{12 - 4} = \frac{1}{8}$.

The hypermetropia in the observed eye is, therefore, for an emmetropic observer always equal to the glass used, minus the distance of the glass from the nodal point of the examined eye.

As the accommodation is equivalent to a convex glass of different focal lengths, it is evident that the observer may substitute his own accommodation for the glass, provided he knows just how much he is using, and how far his nodal point is from that of the examined eye. For example, if the observer sees an eye distinctly, while he is conscious that he is accommodating for ten inches, he knows that the H in the observed eye must be equal to $\frac{1}{10}$ minus the distance between the nodal points of his own and the observed eye. If this is two inches, then $H = \frac{1}{10-2} = \frac{1}{8}$.

The ability to judge of refraction by the degree of tension required of the accommodation, can only of course be brought into play in one condition, that is, where the observed eye is hypermetropic, and even here it is rather a *tour de force* than an essential advantage. We can all of us by a little practice get an approximate idea as to the amount of hypermetropia in a given case, by the amount of tension required of our accommodation in getting a clear view of the fundus, but very few even with any amount of practice ever approximate that precision which can be obtained with infinitely less trouble by means of glasses.

As in the above cases the rays of light passing through the hole of the mirror are parallel, and will continue so if uninterrupted to infinity, it makes no difference in the result whether the observer's eye is close against the instrument or a little removed from it. The only calculation necessary is the distance between the glass and nodal point of the examined eye.

The above directions, which are sufficient for an emmetropic observer whose eye is in a state of rest to determine any condition of refraction, may be summed up in this general rule:—

The ametropia in a given case is equal to the glass used plus the distance between it and the nodal point if the eye examined be myopic, minus the distance if it be hypermetropic.

If, however, the observer is so unfortunate as to be ametropic, then the simplest wa forhim is to reduce his eye to a condition f emmetropia, that is to say, to that condition of refraction that parallel rays unite on his retina; considering that portion of the accommodation which cannot be relaxed as part and parcel of the refraction.

If the ametropic observer does this, then of course the preced-

ing directions will be all that he will have to bear in mind. Should he not wish, however, to pursue this course he will find a little later the methods which he must follow.

Such being the theoretical rules, it remains to be seen how far they are applicable to the wants of the practitioner. The advantages offered by this method may be summed up as follows:—

(1.) In the ability to tell the optical condition of the eye examined independent of the statements of the patient, or amount of vision of the eye.

(2.) In measuring the amount of elevation or depression of given parts of the fundus.

Under the first heading the point which, without doubt, is the most important in a practical point of view, is the determination of the degree of latent hypermetropia.

The use of atropia and the trial by glasses is, and must remain in the vast majority of cases, the most certain test possible, still its use is attended with more or less inconvenience to all, and to some, with so much, that its employment is often impossible. Consequently, any means of diagnosticating the amount of total hypermetropia, which is on the one hand accurate, and on the other free from inconvenience to the patient, cannot fail of being of the greatest value to the practitioner. The only question is, can the ophthalmoscope do this?

From the result of a series of trials with the ophthalmoscope, both before and after the use of atropia, Mauthner does not hesitate to answer this question in the affirmative; laying it down as a law that "*In examinations with the ophthalmoscope* (by the upright image) *the total hypermetropia is revealed.*"[1] This opinion is supported by the citation of the following remarkable case:—

A boy of twelve years presented the usual symptoms of asthenopia. Both concave and convex glasses were declined for distant vision. Even convex $\frac{1}{60}$ was obstinately rejected. The ophthalmoscopic examination brought to light a hypermetropia of $\frac{1}{5}$. The eye was then paralyzed with atropia, and the total *H* was found to be by glasses $\frac{1}{5}$.

[1] Mauthner, Lehrbuch der Ophthalmoscopie, ab. 1, s. 174.

Inasmuch as I have never seen a case of total *H* of so high a grade as $\frac{1}{5}$ where there was no manifest at all, I am unable to corroborate the above case with a precisely similar one from my own practice. I could, however, cite many where the degree of the manifest was very trifling in proportion to the total revealed by the ophthalmoscope, and where the latter obtained by this means differed but slightly from what was subsequently obtained by the use of atropia and glasses. For example, $\frac{1}{36}$ with glasses, $\frac{1}{12}$ with the ophthalmoscope; $\frac{1}{24}$ with glasses, $\frac{1}{6}$ with the ophthalmoscope, $\frac{1}{6}$ with atropia; $\frac{1}{18}$ with glasses, $\frac{1}{6}$ with the ophthalmoscope; $\frac{1}{5\frac{1}{2}}$ with atropia; $\frac{1}{11}$ with glasses, $\frac{1}{4\frac{1}{2}}$ with the ophthalmoscope; $\frac{1}{12}$ with glasses, $\frac{1}{5}$ with the ophthalmoscope, $\frac{1}{5}$ with atropia, etc., etc. Such glittering results as these certainly need but little comment, and their practical application but little explanation, the only wonder being that examinations of this kind are not as universal as the use of the ophthalmoscope itself.

There is one point which at first appears curious, and that is, that we get the most exact and certainly by far the most brilliant results just where we should expect them least; that is, with the highest grades of hypermetropia, at least such has been the writer's experience; so much so that he feels convinced that it is very difficult, sometimes impossible, with young people to tell the lighter degrees of *H* (less than one-fortieth) with the ophthalmoscope, unless indeed atropia has been used. This he believes to be owing to the fact that hypermetropes of a high degree often relax their accommodation entirely while looking inattentively into the distance, and make no effort to call forth their accommodation till their attention is aroused; when, however, their attention is called to some particular object, they instinctively call forth that amount, or very near it, which is demanded for parallel rays. Consequently, under glasses where particular attention is required of them in deciphering the smaller letters of the test card, they refuse to relax their accommodation except to a trifling degree. But when placed in a dimly-lighted room and told to look at a wall which offers a black and diffused surface, and which will appear to them but a little less distinct even when seen in circles of dispersion, they have no difficulty in relaxing their accommodation. But young persons who have say $H\frac{1}{40}$ or

less, see clearly in the distance with so little effort, that they probably never relax their accommodation, preferring to make slight demands on their ciliary muscle than to see in circles of dispersion. Their condition is practically emmetropic, and in the ophthalmoscopic room they relax their A no more than they are accustomed to, accommodating for the plane of the wall which they see distinctly, or at most for parallel rays. We may, however, lay it down as a rule even in these cases, that where little or no H can be detected either by glasses or the ophthalmoscope, little or none exists.

Without being able to accept then, unreservedly, Mauthner's general statement, that the total H can be invariably determined with the ophthalmoscope, we nevertheless believe that a very close approximation to it can almost invariably be obtained.

So much for the ophthalmoscope where atropia has not been used, but there are cases in which it is even superior to the test by atropia and glasses, where the latter indeed utterly fail in giving an idea of the amount of hypermetropia, as the following case will show :—

A bright little girl was brought to me for the purpose of having the exact optical condition of the eyes determined. With a convex one-twenty-fourth vision was decidedly improved ; amounting, however, even with the glass, only to $\frac{1}{5}$ in the right eye, $\frac{1}{10}$ in the left. The same result was obtained under atropia. Glasses of various strengths from $\frac{1}{24}$ to $\frac{1}{12}$ were tried, and still the vision remained about the same. Recourse was now had to the ophthalmoscope, when a total H of $\frac{1}{7}$ was found in the right, $\frac{1}{6}$ in the left eye. The discrepancy between the glass selected by the child and the amount of H as given by the ophthalmoscope was so great that an independent examination was made by another oculist with precisely the same result in each eye. There was evidently a large amount of congenital amblyopia, the only hope of relieving which, certainly lay in careful and systematic exercise through that glass which would produce sharply defined images upon the retina, and this glass could only be ascertained through the ophthalmoscope. Previous experience had already taught me that wonderful results could be obtained in this manner, and I ventured to give an encouraging prognosis.

So, too, in strabismus in children, it is often impossible, from their inability to read, or the irrelevancy of their answers, to get an adequate idea as to the condition of the refraction, even where atropia has been used. And yet the whole question in regard to operative interference may turn on the presence or non-presence of H and its degree. With the ophthalmoscope, however, with a little care, and with a dilated pupil, the exact amount, or what approximates to it very closely, can, as a rule, be ascertained, even with children in arms.

So, too, in any disease in which amblyopia is an element.

One of the most interesting attributes of the upright image is the means which it affords us for determining the various planes which different parts of the fundus often occupy. For, inasmuch as a certain amount of refraction corresponds to a given length of the axis of the eye, we have only to know the refraction of a certain point to know its exact antero-posterior position, and the difference of refraction between two given points must represent their differences of level. We are thus enabled to measure numerically, for example, the amount of excavation of the optic nerve or its projection above the level of the retina; the projection of the choroid or retina from underlying effusion; the height of tumors and their rate of increase; the amount of swelling in the retina; the situations of membranes in the vitreous, etc.

Taking the emmetropic eye as a standard, calculations have been made by various authors to determine what amount of increase or decrease in the length of the optic axis corresponds to a given degree of hypermetropia or myopia. I have calculated for the easy reference of the reader, from the formulas given by Helmholtz,[1] the two following tables, the first representing the amount of decrease in length of the axis due to H, and the second the increase due to M.

[1] Handbuch der Physiologischen Optik, s. 54. Mauthner, Lehrbuch der Ophth., s. 67–226, ab. 1.

Table I.

$H\ \frac{1}{2}$	equals a shortening of	3.97 mm.	$H\ \frac{1}{12}$	equals a shortening of	0.85 mm.
" $\frac{1}{3}$	" " "	2.9 "	" $\frac{1}{14}$	" " "	0.74 "
" $\frac{1}{4}$	" " "	2.3 "	" $\frac{1}{16}$	" " "	0.65 "
" $\frac{1}{5}$	" " "	1.89 "	" $\frac{1}{18}$	" " "	0.58 "
" $\frac{1}{6}$	" " "	1.6 "	" $\frac{1}{20}$	" " "	0.52 "
" $\frac{1}{7}$	" " "	1.4 "	" $\frac{1}{24}$	" " "	0.45 "
" $\frac{1}{8}$	" " "	1.25 "	" $\frac{1}{30}$	" " "	0.35 "
" $\frac{1}{9}$	" " "	1.12 "	" $\frac{1}{40}$	" " "	0.26 "
" $\frac{1}{10}$	" " "	1. "	" $\frac{1}{50}$	" " "	0.21 "
" $\frac{1}{11}$	" " "	0.92 "			

Table II.

$M\ \frac{1}{2}$	equals an increase of	8.6 mm.	$M\ \frac{1}{12}$	equals an increase of	0.97 mm.
" $\frac{1}{3}$	" " "	4.81 "	" $\frac{1}{14}$	" " "	0.82 "
" $\frac{1}{4}$	" " "	3.34 "	" $\frac{1}{16}$	" " "	0.71 "
" $\frac{1}{5}$	" " "	2.56 "	" $\frac{1}{18}$	" " "	0.63 "
" $\frac{1}{6}$	" " "	2.07 "	" $\frac{1}{20}$	" " "	0.56 "
" $\frac{1}{7}$	" " "	1.97 "	" $\frac{1}{24}$	" " "	0.46 "
" $\frac{1}{8}$	" " "	1.5 "	" $\frac{1}{30}$	" " "	0·37 "
" $\frac{1}{9}$	" " "	1.31 "	" $\frac{1}{40}$	" " "	0.27 "
" $\frac{1}{10}$	" " "	1.17 "	" $\frac{1}{50}$	" " "	0.22 "
" $\frac{1}{11}$	" " "	1.06 "			

It should be remembered that these tables[1] are calculated for the actual degree of ametropia present, and not for the glass used in correcting it. The observer must consequently make the proper addition or subtraction according as the glass is positive or negative, and according to the distance at which it is placed from the

[1] I have preferred to keep the original plan pursued in my earlier paper, and to give in the table the actual amount of increase and decrease of the antero-posterior axis that corresponds to the various degrees of ametropia, than to give, as Dr. Knapp has in his tables, the number of the glass by which the different degrees of ametropia are corrected, placed always at a definite distance from the cornea, that is to say at the anterior principal focus of the eye. This position—half an inch from the eye—is entirely too close for the ordinary observer, with whom the place of the instrument varies from one to two, or even three, inches from the cornea.

A closer approach than one inch from the nodal point is rarely if ever obtained by the most exacting expert, and it certainly strikes me as easier and more correct for each observer to make the proper allowance for the distance at which he holds his instrument, and which in a short time becomes uniform, than to be forced, in order to be correct, to advance his glass to a position which he can seldom if ever attain. The discrepancies between the values in the above table and those subsequently calculated by Dr. Knapp are more apparent than real, as the degree of ametropia, as finally obtained, is the same in both. The formulas used in the two cases are, as Dr. Wadsworth has shown, convertible.[2]

[2] Trans. Amer. Ophth. Soc., 1871, p. 87.

nodal point. This varies with different observers from about an inch to two, or even three inches from the nodal point. If, for example, the observer sees the bottom of a hypermetropic eye with $+\frac{1}{8}$, and the distance of his eye from the nodal point is two inches, then the real hypermetropia is not $\frac{1}{8}$, but $\frac{1}{8-2} = \frac{1}{6}$, and it is for the latter degree that the observer must consult the table for the true amount of shortening of the axis.

So, too, with the negative glass, only the distance between the glass and the nodal point must be added. If the observer uses $-\frac{1}{8}$ two inches distant, then the real M is $-\frac{1}{8+2} = \frac{1}{10}$. As the distance from the anterior surface of the cornea to the nodal point is only a little over a quarter of an inch, the observer may, for all practical purposes, make his calculations as between his own and the observed eye.

The formula used in the construction of the table given in

For the convenience of those who prefer the other method, Dr. Knapp's tables[1] *are given below.*

Number of glass in Paris inches.	Displacement of 2d cardinal points in millimetres.	Coefficient of magnifying effect of convex glass.	Coefficient of diminishing effect of concave glass.	S being 1, No. xx Snellen should be read with convex glass in Paris feet.	S. = 1, No. xx. Sn. should be read with concave glass in Paris feet.
30	0.3628	1.0250	0.9762	20.50	19.52
16	0.6812	1.0480	0.9562	20.96	19.12
10	1.0909	1.0793	0.9316	21.59	18.63
8	1.3636	1.1011	0.9159	22.02	18.32
7	1.5584	1.1171	0.9051	22.34	18.10
6	1.8182	1.1396	0.8910	22.79	17.82
5	2.1818	1.1721	0.8720	23.44	17.44
4	2.7272	1.2248	0.8449	24.45	16.90
3½	3.1168	1.2655	0.8265	25.31	16.53
3	3.6363	1.3240	0.8034	26.48	16.07
2½	4.3636	1.4159	0.7738	28.32	15 48
2	5.4544	1.5800	0.7315	31.60	14.63
1¾	6.2499	1.7260	0.7078	34.52	14.08
1½	7 2914	1.9625	0.6708	39.25	13.42
1¼	8.2602	2.3044	0.6427	46.09	12.85
1	10.909	3.4878	0.5837	69.77	11.67

[1] Archiv. of Ophth. and Otol., Knapp, Vol. I., No. 2, p. 397; also Vol. 3, No. 2, p. 1.

the text is that used by Helmholtz[1] and after him by Mauthner.[2]

This is $l_1 l_2 \doteq F_1 F_2$. In this equation l_1 signifies the distance of the object from the first focal point when the object lies in front of it; l_2 is the distance of the image of the object behind the second focal point. F_1, F_2 are the two principal focal lengths.

From $l_1 l_2 = F_1 F_2$ we get directly $l_2 = \frac{F_1 F_2}{l_1}$. As the value of l_1 the distance of the object is given, and F_1 and F_2 are already established values we can at once calculate that of l_2.

In case, however, the object lies behind the first focal point, l_1 will lie in front of the second point, and then both l_1 and l_2 have a negative significance.

The practical application of the formula is as follows: Suppose $M \frac{1}{2}$ exists, what is the increased length of the antero-posterior axis?

The far point of such an eye, calculated from the first nodal point, is two inches or 54.2 mm. But as l_1, the distance of the object, is not calculated from the first nodal point but from the anterior focal point, which is 19.875 mm. in front of it, l_1 therefore equals $54.2 - 19.875 = 34.3$ mm. We have then the following values: $l_1 = 34.3$ mm.; $F_1 = 14.858$; $F_2 = 19.875$. Substituting these values in the equation $l_2 = \frac{F_1 F_2}{l_1}$ we get

$$l_2 = \frac{14.858 \times 19.875}{34.3} = \frac{295.3}{34.3} = 8.6 \text{ mm.}$$

The increase of the antero-posterior axis in $M \frac{1}{2}$ equals 8.6 mm., as seen by the table.

Supposing on the other hand $H = \frac{1}{2}$ is present. l_1 is negative and lies two inches behind the second nodal point, which, in its turn, is 20.3 mm. behind the first focal point; $- l_1$ therefore equals $54.2 + 20.3 = 74.5$ mm. $F_1 F_2$ as before equals 295.3 mm. Therefore $l_2 = \frac{295.3}{74.5} = - 3.97$ m. Thus a hypermetropia of $\frac{1}{2}$ corresponds to a decrease of the antero-posterior axis of 3.97 mm.

[1] Handbuch der Physiolog. Optik, p. 64.

[2] Mauthner, Lehrbuch der Ophth., pp. 67, 221, 226.

The application of the above tables will perhaps be made clearer by some examples, thus:

In a case of glaucoma the edge of the nerve is emmetropic, while the bottom of the excavation is myopic $\frac{1}{8}$. As myopia $\frac{1}{8}$ signifies a lengthening of the axis equal to 1.5 mm. (see Table II.), the depth of the excavations must be, since the edge of the nerve is emmetropic, equal to 1.5 mm. In a second case the border of the nerve and general fundus is myopic $\frac{1}{24}$, the bottom of the excavation is myopic $\frac{1}{8}$; the true extent of the excavation will then be equal to $\frac{1}{8} - \frac{1}{24} = \frac{1}{12}$, $M\ \frac{1}{12} = 0.97$ mm. In a third case the edge of the nerve is $H\ \frac{1}{30}$; the bottom of the excavation is still myopic $\frac{1}{8}$. As $H\ \frac{1}{30}$ represents a shortening of the axis 0.35 mm. and $M\ \frac{1}{8}$ an increase of 1.5, the true extent of the excavation will be $1.5 + 0.35 = 1.85$ mm.

In a case of neuritis, following sunstroke, the centre of the nerve to which the disease was almost entirely confined was hypermetropic $\frac{1}{11}$, the neighboring region was emmetropic. As $H\ \frac{1}{11}$ represents a shortening of the axis $= 0.92$ mm., the protrusion of the nerve was 0.92 mm.

In another case of violent neuro-retinitis in the left eye the centre of the nerve was $H\ \frac{1}{6}$; a little further onward, $H\ \frac{1}{10}$; a little further still, $H\ \frac{1}{16}$; and at the farthest extremity of the field, towards the ora serrata, $H\ \frac{1}{30}$. In the other eye, in which the process has just commenced, the general refraction was $H = \frac{1}{40}$. Assuming then that the refraction of the eyes when in a state of health was emmetropic, and it could not have been far from this, a plan might easily be drawn (as indeed was done) representing the amount of swelling due to the morbid process. This might be subsequently compared with the future progress and recession of the disease, under atrophy, etc., and some interesting results obtained. It is of course very difficult to follow these cases of retinal swelling, such as are common to Bright's disease, from their beginning to their end; still such opportunities do occur, even where the cause is renal, and it appears to me many interesting facts might be obtained from such investigations.

In a certain case a well-marked tumor was observed, situated exactly above the optic nerve, the upper edge of which it overhung. As the media were perfectly clear, a distinct view of the

3

growth in all its detail was obtained. The crest of the tumor was, at the first examination, hypermetropic $\frac{1}{6}$. The lower half of the nerve and all the surrounding fundus was emmetropic; the protrusion of the growth was then 1.6 mm. A subsequent examination was made and the crest of the tumor was found to be $H\ \frac{1}{4}$, the protrusion was then 2.3 mm., and the increase between the two examinations was $2.3 - 1.6$ mm $= 0.7$ mm.

In another case a membrane in the vitreous appeared clearly defined when $+ \frac{1}{3}$ was used, one inch from the nodal point of the examined eye; consequently there would have been, if the retina had occupied the plane of the membrane, $H = \frac{1}{3}{}_{-1} = \frac{1}{2}$. The fundus was in fact emmetropic; the membrane was, therefore, in front of the retina to a degree equal to $H\ \frac{1}{2} = 3.97$ mm.

THE DETERMINATION OF ASTIGMATISM.

The determination of astigmatism by means of the ophthalmoscope has always been considered one of the most difficult, and from its want of accuracy one of the least satisfactory applications of the instrument, and there is no doubt that this is, to a great extent, true. Still, the difficulty in ascertaining the existence of astigmatism, and the uncertainty in establishing its degree, are, I think, due in a great measure to the method adopted, which has usually depended on the fact, first pointed out by Knapp[1] and Schweigger,[2] that in astigmatism the disk was seen elongated in one direction with the upright image, and in the opposite by the inverted.[3] The effect involved in this fact is due to the following causes:—

If we look through a convex lens at an object which is placed within its principal focus, we see it magnified to a certain degree, according to the power of the lens.

[1] Congress at Heidelberg, 1861.

[2] Arch. f. Ophth., IX. ab. 1, p. 178.

[3] This is, however, only true when in the inverted image the glass is held within the focal length of the lens from the eye, a fact which the observer being aware of he can always readily provide for.

If we make, for example, a small cross, the arms of which are of equal length, and view it through a common convex glass, say of three inches focal distance, it appears enlarged, but equally in both directions, as the magnifying power is the same for each arm. If we now add, however, a convex cylindric glass $\frac{1}{6}$ to the spherical, we increase the magnifying power in one principal direction without altering it in the other. The lens is, therefore, equal in one direction to $\frac{1}{3}$, but in the other to $\frac{1}{3} + \frac{1}{6} = \frac{1}{2}$. If we now turn the glass in such a way that the strongest magnifying power shall correspond with the vertical arm of the cross, this will be more enlarged than the horizontal, which is seen through a weaker power, and will consequently appear longer. If we now draw a circle round the arms of the cross in such a way that these shall be the radii, the effect will still be the same, and the circle will appear elongated in the vertical direction because it is more magnified in that direction, consequently it will appear no longer a circle, but an oval.

If, however, we now take a second lens and hold it in the other hand at a certain distance in front of the first lens, just as we do in the indirect method with the ophthalmoscope, then we get an inverted image of the cross, and circle round it, elongated no longer in the vertical but in the horizontal position. The reason of this is that the rays passing through the first lens, whose principal meridians are of different focal power, are refracted unequally, those passing through the vertical meridian where the lens is of two inches focal power more than those passing through the horizontal where it is only three inches. As the rays passing through the vertical meridian are more refracted by the first lens, they will, after passing through the second, come to a focus sooner behind it, and the nearer the rays meet behind a lens the smaller is the image, consequently the vertical line of the cross will now appear smaller than the horizontal, and the circle will now be elongated horizontally.

Applying this principle to the eye, Schweigger deduced the fact that with the upright image the disk in astigmatism is seen elongated in the direction of the meridian of greatest refraction with the inverted image in the meridian of the least refraction. This gives us at once the directions of the principal meridians,

and we have only to find the glass which reduces the distortion to know the kind and amount of astigmatism.

It will be seen at once that an examination must be made by *both* methods, for it may happen that the disk may be elongated anatomically in a vertical, horizontal, or oblique direction, the effect of which might be so counteracted by astigmatism as to make the disk appear round when the ophthalmoscopic examination was made by only one method, but never when both are employed.

Simple and true as all this is on paper, its application to practical wants is limited, from the fact that the distortion under the degrees of astigmatism which usually occur in the human eye, is not sufficient to form a basis for accurate calculation. It may be well to state, however, that the effect is always increased by the observer's alternately withdrawing from and approaching the eye examined, watching as he does so the change in the contour of the nerve.

From the uncertainty and want of delicacy attending this method of examination, it is evident that, in order to make the ophthalmoscope of practical use in astigmatism, we must look for some more sensitive test to act either as a supplement to or a substitute for the one mentioned above.

This we have in the vessels, and especially in the light streak on their centre of curvature. The streak begins to lose its brilliancy and its lateral borders their sharpness of definition the moment the vessel, particularly if of the smaller kind, becomes out of focus even to a very trifling degree. Low degrees of astigmatism, certainly as low as $\frac{1}{48}$, can be detected by this test, provided the accommodation in both the observed and observing eye is perfectly relaxed. On this account, it is much easier to determine the defect if slight, when due to *M* than to *H*, and I do not think it is too much to say that even $\frac{1}{60}$ can then under favorable conditions be pronounced upon.

If we consider the optic disk as the centre of a circle, and all the vessels large and small radiating from it as so many straight lines, we have in the fundus of the eye itself a representation of Dr. Green's test for astigmatism, in which the principal branches of the central artery and veins represent the vertical lines, and

the small vessels leaving the edge of the disk the horizontal and oblique. It may be said that the principal trunks of the central artery and vein do not always run exactly vertical. This is true, but such is their general tendency, and the fact that the vessels do not continue in their original vertical course is of itself an assistance to the diagnosis.

The practical application of this is as follows: If we look with the ophthalmoscope through the cornea of an astigmatic eye to the retina beyond, the effect is precisely the same as if we were looking through an astigmatic glass, and the vessels radiating from the optic nerve will then appear just as the radiating lines do in the common test when seen through a cylindric glass, *most distinct in the meridian of greatest ametropia.* This gives us at once the direction of one of the principal meridians, and we know that the direction of the other must be at right angles to it. Having thus found out the direction of the principal meridians, we have then only to determine the refraction of each meridian separately, and the difference between the two will be the amount of astigmatism.

If, for example, in a certain case the vertical vessels appear perfectly distinct, and are only rendered less so by glasses, one of the principal meridians of the eye must be emmetropic. If, however, the fine horizontal vessels are only made distinct by a concave $\frac{1}{24}$, then the second principal meridian must be myopic $\frac{1}{24}$, and inasmuch as the first was emmetropic, the amount of simple astigmatism present must be one twenty-fourth. So also if it had been *H* instead of *M*, and convex instead of concave glasses used.

If both meridians are myopic, but one more so than the other, then compound astigmatism is present with *M* in all meridians, but more pronounced in one. If, for example, the horizontal vessels are seen distinctly only with $-\frac{1}{12}$, while the vertical ones can be seen with $-\frac{1}{24}$, the general myopia then equals $\frac{1}{24}$, and the astigmatism, that is the discrepancy between the two principal meridians, is $\frac{1}{12} - \frac{1}{24} = \frac{1}{24}$. The neutralizing glass would then be $-\frac{1}{24}s \bigcirc -\frac{1}{24}c$. Axis horizontal.

So too if it had been *H* instead of *M*, and plus instead of minus glasses had been employed.

It is a little puzzling for those who are not much accustomed to the determination of astigmatism, to understand how it is that the vessels, as do radiating lines, always appear most distinct to an emmetropic eye, in the meridian of the greatest ametropia, instead of, as would appear more rational, in that of the least. It would, for example, seem more natural, that inasmuch as the vertical vessels were seen in the above case most distinctly, that the vertical meridian should be the one which deviated least from the normal. But it must be borne in mind that the rays which form the vertical boundary of these vessels are, in fact, horizontal rays, and as such pass through, not the vertical, but the horizontal meridian, and as this is emmetropic they are readily focussed on the observer's retina. On the other hand, the rays which form the boundary of the horizontal vessels are vertical rays, and pass through the vertical meridian, which is myopic, and consequently the horizontal vessels are indistinct, although this meridian is, in fact, emmetropic. This of course holds good for all kinds and degrees of astigmatism.

The writer readily admits that this method is also, though by no means in the same degree, wanting in accuracy, and is not to be looked upon at all as a substitute for the trial by glasses, but is to be used in co-operation with it. When so employed, the ophthalmoscope often renders important service in revealing to us at a single glance, as it were, the nature of the anomaly and the general direction of the principal meridians, when to have obtained them by glasses would have been an affair of hours. In cases of mixed astigmatism this holds true in a marked degree, and I cannot forbear, for the sake of their practical bearing, from citing the two following cases:—

A young lad was examined by me, who, it was alleged by his parents, was nearly "blind" in one eye. On testing the eyes, the left was found to have a trifling degree of hypermetropia ($\frac{1}{50}$) with vision one. In the right eye, however, vision was reduced to $\frac{1}{20}$, that is, Snellen C. could only be read in five feet. A few trials were made with glasses with no material improvement in vision. In looking into the eye with the ophthalmoscope the nerve appeared distorted and drawn out vertically, while at the same time its outline was indistinct in all directions, as were also

all the vessels. On using the accommodation, however, the vertical edge of the vessel became well defined, as did all the vessels, so long as they ran in a vertical direction, but as soon as they deviated from this they at once became indistinct, and in proportion to the amount of the deviation. This was very apparent at a certain place where one of the larger vessels divided, sending off a branch almost at right angles to the original direction of the vessel. The branch which continued in the vertical direction remained perfectly distinct, and the light streak in the centre of its walls clearly defined, while that running at right angles to it, that is, horizontally, was indistinct and evidently much out of focus, as were, in fact, all the vessels, large and small, running in this direction, and no amount of tension or relaxation of the accommodation made them clearly defined.

It was manifest that astigmatism was present, and that the directions of the principal meridians were vertical and horizontal. It was evident, too, that as it required the action of the accommodation to make the vertical vessels distinct, that there must be hypermetropia in the horizontal meridian. In determining the degree, it was found that the strongest glass through which a certain fine vertical vessel remained distinct at two inches distance was a convex $\frac{1}{16}$, the hypermetropia in the horizontal meridian was therefore equal to $\frac{1}{16-2}=\frac{1}{14}$.

As the horizontal edge of the nerve and all the vessels running horizontally remained indistinct, even when the observer's accommodation was perfectly relaxed, it was evident that the rays which formed the horizontal boundary of the nerve and vessels must leave the eye as convergent, and as these rays are vertical rays, the eye must be myopic in the vertical meridian. It was found that the weakest glass under which the horizontal boundary of the nerve and vessels became sharply defined was $-\frac{1}{10}$, the vertical meridian was therefore myopic equal to $-\frac{1}{10+2}=\frac{1}{12}$.

The case was therefore one of mixed astigmatism, in which the vertical meridian was myopic $\frac{1}{12}$, and the horizontal hypermetropic $\frac{1}{14}$, and the discrepancy between the two meridians was $\frac{1}{12}+\frac{1}{14}=\frac{1}{6\frac{1}{2}}$. With a bicylindric glass $-\frac{1}{12}$ and $+\frac{1}{14}$ vision at once rose from $\frac{1}{20}$ to $\frac{8}{20}$. It was in fact increased eightfold. It was subsequently found from a careful examination that $-\frac{1}{13}$c.

and $+\frac{1}{12}$c. was preferred. With this glass, vision became one-half.

In another case, where the patient suffered a great deal from asthenopic symptoms, vision was found to be only one-fifth in either eye. Reading was performed at six inches, while in sewing the patient declared that she had to exercise great care to keep from wounding her nose with the needle. As in the former case, spherical glasses were tried with but little improvement of vision. On looking into the eye, here too neither the nerve nor any of the vessels appeared distinctly defined. On accommodating, however, it was seen that although the vertical and horizontal vessels still remained comparatively indistinct, those that originally ran, and those which later in their course assumed an oblique direction upwards and inwards and downwards and outwards, suddenly came sharply into view, while those which ran at right angles became the most indistinct of all. The same effect was noticed all over the fundus, especially in following along the course of a vessel, some of whose branches appeared perfectly distinct, while those running at right angles were much out of focus. This meridian was found to be myopic $\frac{1}{20}$, the opposite hypermetropic $\frac{1}{11}$. With these glasses properly arranged, vision rose from one-fifth to two-thirds, and the patient could read Jaeger No. 4 at ten inches, and sew with ease at twelve. The left eye was $\frac{1}{18}$c. $\Gamma - \frac{1}{20}$c. $V = \frac{1}{2} +$.

Irregular Astigmatism.—This can, as a rule, be readily detected by the fact, that a given vessel, while maintaining an undeviating course, can only be clearly defined for a comparatively short distance at a time, no matter what glass is used.

The vessel, while continuing in precisely the same direction, will, for a short distance, appear in focus with the light streak perfectly defined, and then be suddenly interrupted by a portion which is out of focus, and perhaps a little displaced laterally. And of two neighboring vessels, one will be sharply defined and the other not. A change of glass, or sometimes a change in the observer's accommodation, will reverse the original order of things, making the part which was indistinct clear and the other blurred. This very often happens when such cases are examined with a dilated pupil, through portions of the cornea which are

widely separated from each other, as for example, through the upper and lower borders. The ability to diagnosticate irregular astigmatism with the ophthalmoscope, is not a difficult matter as a rule, and it will often save the surgeon a world of trouble in uselessly trying to make an accurate adaptation of glasses, an approximate one being all the circumstances will allow.

It may be well to mention here, that irregular astigmatism, at least of large degrees, can be detected by the use of the mirror alone at a distance, by the play of light and shadow which takes place on rotary movements of the mirror, and oftentimes by the distorted image of a portion of the fundus with its sudden appearance and disappearance. This method of examination, and the appearances which follow, are similar to those obtained in examination for conical cornea.

DIRECTIONS TO BE OBSERVED IN CASE THE OBSERVER IS AMETROPIC.

The observer being myopic.

Proposition I. *For a myope to examine an emmetropic eye.*—It is very evident that as the rays which leave an emmetropic eye are parallel, that the myopic observer, provided he can relax his accommodation, will simply have to use the glass behind the mirror, which neutralizes his myopia, that is to say, which brings parallel rays to a focus on his retina. If a concave $\frac{1}{8}$ does this, then $\frac{1}{8}$ will be the glass employed, and whenever he sees an eye distinctly with this glass, he knows that the rays which leave it must be parallel and consequently it must be emmetropic.

But it may happen that the myopic observer, like the emmetropic, cannot relax his accommodation, while using the ophthalmoscope. This will make him just so much more myopic, and instead of using, say $\frac{1}{8}$, which fully neutralizes his myopia, he will with the ophthalmoscope have to use, in order to bring parallel rays to a focus on his retina, $\frac{1}{6}$ or $\frac{1}{5}$. Under these conditions his eye is equivalent to a myope's of $\frac{1}{6}$ or $\frac{1}{5}$, whose accommodation is entirely relaxed. The observer will then know that when

the eye under examination is seen clearly with this glass it must be emmetropic.

As the rays leaving the emmetropic eye will always strike upon the glass used as parallel, it is evident that the distance between the two eyes need not be here taken into account, and that, consequently, the observer may be one or more inches from the observed eye, as he pleases.

Proposition II. *For a myope to determine the degree of myopia in the observed eye.*—If the observer does not wish to wear a correcting glass, which is often inconvenient and clumsy, the simplest way for him is to proceed with the examination just as an emmetrope would, and find by trial with what glass he sees the fundus most distinctly, his accommodation being of course relaxed, and then to take into account the amount of his error in refraction; saying, for example, a myope of $\frac{1}{6}$ finds that he sees the fundus of the examined eye with concave $\frac{1}{3}$, what is the amount of M present?

The observer knows that a part of this glass $= \frac{1}{6}$ is employed in neutralizing his own myopia; consequently to get the true glass through which the fundus would be seen independent of his error of refraction, he must subtract this $\frac{1}{6}$ from $\frac{1}{3}$ used, $\frac{1}{3} - \frac{1}{6} = \frac{1}{6}$. Now assuming the distance to be two inches, we have $\frac{1}{6+2} = \frac{1}{8}$. The amount of myopia in the examined eye is therefore equal to $\frac{1}{8}$, and a myope of $\frac{1}{6}$ will have to use $-\frac{1}{3}$ at two inches, in order to see the fundus clearly.

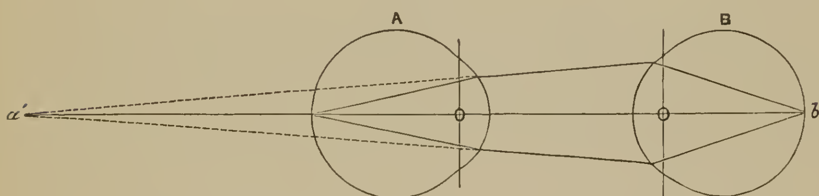
From this it will be seen that the myope of even a medium degree will have to use very strong glasses to see the fundus of an eye which is only moderately myopic. Now as ophthalmoscopic cases do not usually contain these strong glasses, it follows that the myopic observer must renounce in many cases examinations by the upright image.

By far the best way of avoiding this difficulty, is to have a small movable slide containing the proper glass fitted to the back of the instrument. This will not interfere with the use of the glasses ordinarily placed in the clip. There is no real disadvantage in seeing through two concave glasses; on the contrary, according to Mauthner, an actual advantage over one very strong

glass, inasmuch as the image by the use of the two weaker glasses is more aplanatic than where one strong glass is employed. The lessening in illumination is so small as to be of no consequence at all.

PROPOSITION III. *For a myopic eye to determine the degree of hypermetropia in a given case.*—Let A represent a hypermetropic eye of $\frac{1}{8}$; rays coming from the fundus of such an eye will diverge as if they came from a point eight inches behind the nodal point at a'. If now a myope of $\frac{1}{10}$ (B), place his eye two inches in front of the observed eye, then the rays which enter his eye will diverge as if they came from a point ten inches in front

FIG. 6.



of his nodal point, that is to say, his far point, and as his eye is just adapted for such rays, they will come to a focus on his retina, and he will get a clear view of the fundus without the use of any glass.

If the observer's eye is at four inches from the observed eye, then the rays which enter his eye will diverge as if they came from a point twelve inches in front of his nodal point, the observer will only have to be myopic $\frac{1}{12}$ to bring such rays to a focus. The hypermetropia in the observed eye is then always greater than the observer's myopia by as much as the observer's eye is distant from the observed. In the above case $H=\frac{1}{10-2}=\frac{1}{8}$. $H=\frac{1}{12-4}=\frac{1}{8}$.

If the hypermetropia in the observed eye is greater than the observer's myopia (the distance between the two eyes being taken into consideration), it is evident that the rays will emerge so divergent that they will no longer meet upon the observer's retina, but behind it. In order to bring such rays to a focus he must make himself so much more myopic. This he does by a convex glass which he finds by trial just as an emmetrope would. For

example, a myope of one-eighteenth finds that he needs a *convex* $\frac{1}{18}$ to see the fundus distinctly. If he adds this glass he is no longer myopic $\frac{1}{18}$, but $\frac{1}{18}+\frac{1}{18}=\frac{1}{9}$. Now we have just found that the H equalled the M minus the distance, and as the $M=\frac{1}{9}$ we get $H=\frac{1}{9-2}=\frac{1}{7}$.

The observer in this case may use his A instead of a lens, providing he can estimate the amount.

If, however, the hypermetropia in the observed eye is less than the myopia of the observer (the distance between the eyes being taken into account), it is evident that the rays emerging from the eye will be so little divergent, that the stronger myopia of the observer will cause them to meet in front of his retina. The observer must make himself less myopic in order to bring such rays to a focus on his retina; this he does by means of a *concave* glass. For example, a myope of $\frac{1}{6}$ can only see the fundus in a given case with $-\frac{1}{18}$, what is the H of the observed eye? By placing the concave glass before his eye, he has reduced his myopia so that he has no longer $M=\frac{1}{6}$, but $\frac{1}{6}-\frac{1}{18}=\frac{1}{9}$. As we have previously found that $H=M$ minus the distance, we have $H=\frac{1}{9-2}=\frac{1}{7}$.

The observer being hypermetropic.

Proposition IV. *For a hypermetropic observer to see an emmetropic eye.*—Inasmuch as the rays leaving an emmetropic eye are parallel, the observer, in order to bring such rays to a focus on his retina, will simply have to neutralize his manifest hypermetropia. If he is H $\frac{1}{12}$, then he will simply have to place a convex $\frac{1}{12}$ behind the mirror.

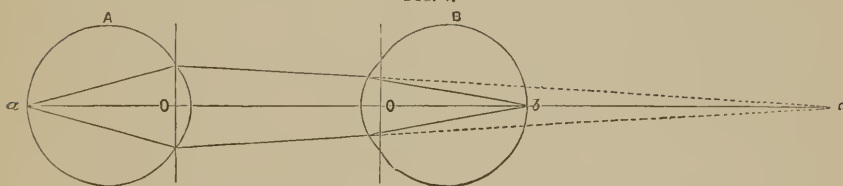
He may find, however, that with the opthalmoscope he does not relax his accommodation. His hypermetropia, consequently, will be reduced by just the amount of accommodation which he is using. And he may find that instead of using say a convex of $\frac{1}{12}$, which fully neutralizes his manifest H, he will, with the ophthalmoscope, require only $\frac{1}{24}$ to bring parallel rays to a focus. Under these conditions his eye is in fact equal to a hypermetrope's of $\frac{1}{24}$, who can entirely relax his accommodation, and the observer will then know that an eye seen distinctly through this glass must be emmetropic. It may happen in this way that a person who is

slightly hypermetropic for the distance, becomes for the ophthalmoscope emmetropic, and so has to use no glass. For example, a hypermetrope of $\frac{1}{36}$ may find on account of his inability to relax his accommodation, that in order to see an emmetropic eye he needs a concave $\frac{1}{36}$. The amount of accommodation which he uses would then only be $\frac{1}{18}$ and many inexperienced observers use $\frac{1}{12}$. In this case the observer is virtually myopic, and must proceed as such.

The observer may of course use his accommodation in all cases instead of a convex-glass, that is to say, the lens in his own eye instead of one behind the mirror. He would, however, in this case have to know just what amount of tension of his ciliary muscle corresponds to a given glass.

Proposition V. *For a hypermetropic observer to determine the amount of myopia in the observed eye.*—Let *A* be myopic $\frac{1}{8}$; rays of light coming from *a* will meet eight inches in front of *A's* nodal point at *a'*. If *B* who is hypermetropic $\frac{1}{6}$, places his eye two inches from *A*, then rays from *A* would meet, if unin-

Fig. 7.



terrupted, at a point just six inches behind *B's* nodal point. Now as *B's* eye being hypermetropic $\frac{1}{6}$ is adapted for such rays, they will be brought to a focus on the retina. Consequently *A's* myopia must be equal to *B's* hypermetropia plus the distance, $M = \frac{1}{6+2} = \frac{1}{8}$. From this it follows that a hypermetrope of a certain degree can see the fundus of a myope of a certain degree without any glass.

If, however, the myopia of the observed eye is greater than the observer's hypermetropia, it is evident that the rays emerging from the eye examined will be so convergent that they will meet in front of the observer's retina; to bring them to a focus he must make himself more hypermetropic. This he does by means

of a concave glass, which he finds just as an emmetrope does by trial. For example, a hypermetrope of $\frac{1}{18}$ finds that he, with his accommodation relaxed, sees the fundus distinctly in a given case with concave $\frac{1}{9}$, what is the myopia in the observed eye?

By putting the concave $\frac{1}{9}$ before his eye, the observer has made himself just so much more hypermetropic. He is consequently no longer hypermetropic one-eighteenth, but $\frac{1}{18}+\frac{1}{9}=\frac{1}{6}$. Now as the myopia in the observed eye is equal to the observer's hypermetropia plus the distance, we get $M=\frac{1}{6+2}=\frac{1}{8}$.

If, however, the myopia in the observed eye is less than the observer's hypermetropia (the distance between the two eyes also taken into consideration), rays emerging from the observed eye will not be convergent enough to meet on the retina, but behind it. To make such rays meet on his retina he must make himself less hypermetropic. This he does by a convex glass which he finds by trial. For example, a hypermetrope of $\frac{1}{9}$ sees in a given case with a convex $\frac{1}{18}$, what is the degree of myopia present in the examined eye? By adding the convex $\frac{1}{18}$ to his eye, the observer has reduced his hypermetropia, making himself no longer hypermetropic $\frac{1}{9}$, but $\frac{1}{9}-\frac{1}{18}=\frac{1}{18}$. Now as the myopia equals the hypermetropia plus the distance, we get $M=\frac{1}{18+2}=\frac{1}{20}$. Thus we see that a hypermetrope may, according to circumstances, in estimating myopia, use no glass at all, or a convex, or a concave one.

Proposition VI. *For a hypermetropic observer to estimate the amount of hypermetropia in the examined eye.*—The best way in this case is for the observer to find by trial with what glass he sees the fundus most distinctly, and then to take his own error of refraction into consideration. For example, a hypermetrope of $\frac{1}{18}$ sees the examined eye with convex $\frac{1}{9}$, what is the hypermetropia present? The observer knows that a part of this, equal to one-eighteenth, is employed in neutralizing his hypermetropia, consequently to get at the true glass which would be used independently of his error in refraction he must subtract this $\frac{1}{18}$. $\frac{1}{9}-\frac{1}{18}=\frac{1}{18}$. As the observer has thus neutralized his hypermetropia, he is virtually emmetropic, and knows that the H present must be equal to the glass used minus the distance. $H=\frac{1}{18-2}=\frac{1}{16}$.

THE DETERMINATION OF THE REFRACTION OF AN EYE BY THE MIRROR ALONE, AND BY MEANS OF THE INVERTED IMAGE.

It has been already shown how, with a myopic eye, we get with the mirror alone an inverted aerial image of a small portion of the fundus, an image which is situated in front of the eye, and at the distance of its far point.

With a hypermetropic eye, on the contrary, we get a virtual and erect image behind the eye and at a distance equal to the degree of the hypermetropia.

If, then, we could only tell in a given case whether the image which we see is inverted or upright, then we should know at once whether the eye examined was myopic or hypermetropic. There are various ways of ascertaining this:

(1.) Both the image and the field of view are larger (except in very extreme degrees) in myopia than in hypermetropia.

(2.) In myopia the image moves in a sense contrary to that of the observer's head, and the more so the farther it is in front of the observed eye. In hypermetropia it moves with the head of the observer, and the excursion is less.

(3.) The observer, as a rule, can tell whether he is accommodating for an image which lies in front of the eye, examined or behind it, the difference in the position of the images even in high degrees of the two kinds of ametropia being considerable.

Suppose, in this connection, the observer is emmetropic, and that his near point lies in six inches. He can then accommodate for an object at that distance but no nearer. In a given case in putting up the mirror he gets an image which, on his gradually approaching his head and exerting in a corresponding degree an increased tension on his accommodation, remains distinct up to a certain point, when suddenly it begins to grow a little indistinct. Withdrawing his head a trifle till the image is clearly defined again, the observer knows that the image must lie six inches in

front of his own eye. And if the distance between this and the observed eye is greater than six inches, the image must then lie in front of the eye examined, which is consequently myopic.

But, on the other hand, supposing the image does not grow indistinct at all till the observer gets close up to the observed eye, say two inches from it, he then knows that the image cannot lie in front of the observed eye, which is only two inches distant, for if it did it would be so blurred as not to be recognizable, being so far within the limits of his accommodation. The image must lie behind the eye, which must be consequently hypermetropic.

The nature of the refraction having been ascertained in this way it remains to determine its degree. The application of the mirror in this manner and for this purpose is at the best but limited, as it is only in cases of high degrees of ametropia that it is of any service at all, and only in cases of great myopia where its advantages outweigh its difficulties and give it a practical importance. Theoretically it would, of course, be just as applicable to *H* as *M*, the only difficulty being the telling just how far behind the observed eye the vertical image of a small segment of the fundus really is. The difficulty is, however, so great, either by means of the accommodation or of glasses, that it is hardly worth while attempting it, especially when with the upright image the fundus of a hypermetropic eye is so readily and distinctly seen —an advantage which does not obtain from the very construction of the eye in myopia of high degrees, the illumination of which for many reasons is difficult and insufficient. It is therefore to the illustration of this latter condition alone that our examples will be applied.

We will begin for the sake of simplicity, by supposing that the observer is himself myopic, for example $\frac{1}{8}$. His far point would then lie at 8 inches, and any object at a greater distance than this would appear indistinct. Such an observer in a given case gets an image with the mirror alone, and at the ordinary distance, say 16 inches, an image which though recognizable as to its general outlines is not sharply defined. Approaching the eye till the definition becomes perfect and stopping the moment it does so, the observer knows that the image must lie at his far point, or eight inches in front of him. The observed eye is still, how-

ever, twelve inches from him; consequently the image must lie four inches in front of it, and the myopia be equal to $\frac{1}{4}$. Suppose, however, the distance between the two eyes had been 10 instead of 12 inches, then the distance of the image in front of the observed eye would have been $10-8=2$ inches, and the myopia would have been equal to $\frac{1}{2}$. Again suppose the observer had been myopic $\frac{1}{6}$ and the distance between the eyes was 10 inches, then the place of image would have been $10-6=4$, and $M=\frac{1}{4}$. The observer has then only to know his own myopia and the distance between the two eyes, and to subtract the former from the latter to know the amount of M in the observed eye.

If, however, the observer is not myopic naturally, he can make himself so very readily by putting a convex glass behind the mirror. If he be emmetropic and can fully relax his accommodation, and uses $+\frac{1}{8}$ his far point will then lie at 8 inches, as in the former case, and he now proceeds in precisely the same way as if he was naturally myopic, and in the manner just related; if he cannot fully relax his accommodation, then allowance must be made for this. If, for example, he involuntarily uses what is equal to $+\frac{1}{24}$, then he is already myopic $\frac{1}{24}$ and will have to add the difference between that and $\frac{1}{8}$. $\frac{1}{8}-\frac{1}{24}=\frac{1}{12}$, and with this glass he will be in precisely the same condition as a myope of $\frac{1}{8}$ or an emmetrope with $+\frac{1}{8}$ who can relax his accommodation entirely. If, on the other hand, the observer is hypermetropic he must first neutralize this. If, for example, he has $H=\frac{1}{24}$ he will, in order to make himself equal to a myope of $\frac{1}{8}$, have to use $\frac{1}{8}+\frac{1}{24}=\frac{1}{6}$ and so on.

In all these cases requiring the addition of a convex lens the observer might have used his accommodation instead of the glass, provided he had such a control over it as to be able to estimate precisely what amount he was using.

It may even happen, that the observer's myopia is so great that he will be forced to use a concave glass in order to bring his far point to 6 or 8 inches. It is better to do this when the M is greater than $\frac{1}{6}$, as the difficulty increases when the observer has to approach closer than this to the image. If he has $M=\frac{1}{4}$ then he will need to carry his far point out to 8 inches $\frac{1}{4}-\frac{1}{8}=\frac{1}{8}$.

DETERMINATION OF ASTIGMATISM WITH THE MIRROR ALONE.

Many years ago Mr. Bowman[1] pointed out the fact that he had been led to the detection of regular astigmatism and the directions of the chief meridians by the use of the mirror of the ophthalmoscope in the way which he had previously suggested for conical cornea. The mirror is to be held at about two feet from the eye, and its inclination rapidly varied so as to throw the light on the eye at small angles to the perpendicular, and from opposite sides, in successive meridians. The area of the pupil then exhibits a somewhat linear shadow in some meridians rather than in others. Little or no effect occurs, however, from moderate or even from comparatively well-marked deviations from the normal curvature.

NOTE.—Mr. Couper[2] has dilated somewhat upon this method, and has proposed the use of a special mirror of thirty inches focal length, with which the eye is illuminated from a distance of some three or four feet. In this way Mr. Couper asserts that very low degrees of astigmatism can be detected, and the directions of the principal meridians ascertained. There are many objections in the author's mind, theoretical as well as practical, to this method, in whose hands, perhaps from want of skill, it has not proved either "easy or expeditious." Mr. Couper himself admits that it is not very well adapted to several of the commonly occurring forms of astigmatism, and it would hardly seem advisable to take the trouble of procuring a special and uncommon form of mirror for so limited a sphere of action. Especially when not only the presence and kind, but even the degree of every form of astigmatism can be accurately and easily measured with the ordinary mirror, by the use of the upright image in the manner already explained in the foregoing pages.

DETERMINATION OF THE REFRACTION BY MEANS OF THE INVERTED IMAGE.

Since the nearer an image is formed behind a lens the smaller it will be, it follows that the inverted image with a myopic eye,

[1] See Refrac. and Accom., Donders, p. 490, 1864.

[2] Fourth International Congress Report. London, 1872, p. 109.

from which the rays already emerge, as convergent, must be smaller than with an emmetropic eye, when the same lens is used with each, and is held at or within its focal length from the eye. On the other hand the image will be larger with a hypermetropic than with a normal eye under the same conditions.

In this way we can often tell by the size of the image alone whether an error in refraction is present, and what its character is; but only in a general way, and only when the defect is of a marked degree.

We are able, moreover, to supplement the evidence gained in this manner by slight to-and-fro movements of the lens.

With a myopic eye the size of the image, for example, of the disk increases as we draw the lens away from the eye. With hypermetropia, on the contrary, it decreases as the lens recedes. In emmetropia the image remains the same for all distances of the lens.[1]

Various appliances have from time to time been brought out for the purpose of ascertaining the exact position and size of the inverted image formed through the objective glass in different degrees of ametropia with the aim of thereby determining its exact degree. Thus Hasner produced an ophthalmoscope with sliding tubes and a graduated scale on the principle of some of the optometers. Coccius, an ocular composed of two lenses, also in a sliding tube. Colsmann, a plane convex lens, with a scale engraved transversely on the plane surface, by which the size of the image could be numerically measured and some idea of the degree of refraction estimated. But all these, together with other devices, have been in turn tried and passed into neglect either as useless or inexpedient.

The observer can, however, if he thinks it of sufficient importance, gain some insight, not only into the kind of ametropia present, but also, approximately at least, as to its degree.

To do this he has only to reduce all eyes to a greater or less degree of myopia by putting before them a convex lens of a constant strength, and then proceed to estimate the place of the image precisely as if the observed eye was really myopic. Let $+\frac{1}{6}$ be

[1] Giraud Teulon, Annales d'Oculistique, 1869, Sept., p. 95.

either held close before the eye, or better still, placed in the spectacle frame of the test case. Rays leaving an emmetropic eye are parallel, and consequently such rays, after passing through the lens, will come to a focus at six inches in front of the glass where the image would lie.

Rays from a myopic eye would strike the glass as already convergent, and the image would then be inside of the focal distance, and to a degree corresponding to the amount of the *M*. On the other hand, the image would lie with the hypermetropic eye farther from the glass than its principal focus, and the farther the greater the degree of *H*.

In a given case the observer sees the image distinctly, while his *A* is perfectly relaxed through $+\frac{1}{6}$. The image must then be six inches in front of him. The distance between his and the observed eye—or rather between his eye and the glass—is 12 inches; the image of the observed eye must be then six inches in front of the glass, or at its principal focus. To produce an image at this place the rays must leave the observed eye as parallel, consequently, the observed eye must be emmetropic. In a second case the observer, through $+\frac{1}{6}$, sees the image while he is only 9 inches from the glass, consequently, the image must be only 3 inches in front of the observed eye, considerably within its principal focus. To produce an image in this place, the rays leaving the eye must have been convergent, consequently, the observed eye is myopic, and the $M = \frac{1}{3} - \frac{1}{6} = \frac{1}{6}$.

Again, the observer sees the image clearly when the distance between his eye and the glass is 16 inches. The image must be therefore 10 inches in front of the observed eye, and beyond the principal focus. The rays coming from the observed eye must have been divergent, and the eye hypermetropic. $H = \frac{1}{6} - \frac{1}{10} = \frac{1}{15}$.

The distance between the glass and the nodal point has been neglected as the method, at the best, has no sufficient claim to exactness. Its range of usefulness is indeed very limited, still it may often be of advantage to those who use the inverted image, and that only.

THE DETERMINATION OF ASTIGMATISM BY MEANS OF THE INVERTED IMAGE.

From what has already been said in connection with astigmatism, as observed by the upright image, it will be remembered that when this irregularity of refraction is present, we see in the direct method the disk elongated in the meridian of greatest curvature, because the lenticular system being stronger in that direction, the magnifying power is greater. With the inverted image we see the disk elongated in the opposite direction, that is, in the direction of the weakest meridian, because the image being formed behind the lens it is less reduced in that meridian than the others.

Thus, as Knapp and Schweigger showed by the alternate use of the upright and inverted image we can not only detect the presence of astigmatism, but also the direction of its principal meridians. This, however, only holds good, as will be explained a little later, when the glass is held at a distance less than its focal length from the eye observed.

It was in accordance with this restriction that Javal[1] pointed out the fact that it was not necessary to have recourse to the alternate use of both methods, but that the same interchange in the form of the disk could be effected with the inverted image alone with the great advantage of keeping a continuous picture of the disk before the eye of the observer—a picture which gradually changed its form, through all the phases of an oval with its longest diameter in one direction, to a circle, and then to an oval again, with its longest diameter in the opposite direction. The change is brought about by simply varying the distance of the object-glass from the observed eye within the limits set by the image of the disk becoming smaller than the pupillary space, either from too close an advancement towards or too great a separation of the lens from the eye.

Giraud Teulon[2] has amplified this idea of Javal's in a most ex-

[1] Etudes Ophth., Wecker. Tome II. fasc. 2, p. 836. 1867.

[2] Ann. d'Oculistiques. Sept. et Oct., p. 95. 1869.

tended and elaborate mathematical discussion, with a clearness of style and a wealth of formula as varied as it is vast. To this essay, which is beyond the scope and character of the present work, the mathematical reader is referred for particulars. To such as are not, the following résumé, condensed from the original so far as its ophthalmoscopic bearing is concerned, will be of service as well as interest.

(1.) In the emmetropic eye, when the accommodation is relaxed, the image of the optic disk remains identically the same in character, and of the same size for every distance of the lens.

(2.) In an eye which is regularly ametropic the image decreases (*H*) or increases (*M*) with the distance of the lens. It always preserves, however, its original form, remaining circular if the disk is circular, and oval if it is oval.

(3.) In an astigmatic eye the recession of the lens causes a variation not only in the dimensions but also in the form of the image itself, *i.e.*, of the disk. If the image be oval, with its long axis in a certain direction, when the lens is a short distance from the eye, it becomes exactly circular when this distance equals the focal length of the lens. At a greater distance, however, the direction of the long axis of the oval changes, becoming perpendicular to its former direction.

Thus nothing is easier than to determine whether an eye is or is not astigmatic. Any positive lens which is suitable to produce an inverted image of all the diameters of the optic disk will solve the problem and indicate at the same time the direction of the principal meridians, and will, moreover, with a little care on the part of the observer, point out the nature of the defect, thus—

When the lens is close to the eye, the long diameter of the oval belongs to the meridian of the least refraction. From this position of the lens to one which is equal to its focal length from the eye,[1] when the image is exactly circular, the different diameters of the image have either increased or decreased. Those which have increased indicate myopic, those which have decreased hypermetropic meridians.

[1] Plus the distance of the anterior focus, one-half inch about.

If the two principal meridians have decreased or increased at once, that which has done so most rapidly belongs to the most ametropic meridian. This shows compound astigmatism—general *M* or *H*, with increased *M* or *H* in one meridian.

Beyond the distance at which the image is exactly circular the conditions are reversed and become the same as in the upright image—that is, the long diameter of the oval is in the meridian of the greatest curvature.

The principle contained in the above, may perhaps be more tersely expressed as follows:

If the long diameter of the oval contracts when the lens is moved from the eye so as to become equal to the short and thus make a circle, then the astigmatism is due to *H*. If, on the contrary, the short diameter expands so as to become equal, at the focal distance of the lens, to the long, and thus make a circle, then it is due to myopia.

If all the diameters contract, but one contracts more than the rest, then general *H* is present with *H* increased in one meridian. If all increase, but one more than the rest, then *M* is present with *M* increased in one principal meridian. The astigmatism is compound.

If one diameter expands and one contracts, then both *M* and *H* are present and the astigmatism is mixed.

We see from this, that astigmatism may be detected in two stages, as it were, in the passage of the lens: first, when it is moved from a point close to the eye to a distance equal to its focal length; secondly, from this point outwards, to a distance limited to the contracting field of view by which the image of the disk is rapidly shut out by that of the iris.

It is in this last stage from the focal distance outwards that the effect is most pronounced as a rule. It is, however, better to make the lens move through the entire course. Great care must be taken not to rotate the lens at all, but to maintain it as exactly as possible in a plane perpendicular to its line of motion.

So sensitive is this test that Javal declares that even $\frac{1}{48}$ can be detected by it. Thus this method should never be omitted in making the preliminary examination with the inverted image,

for by a few passes back and forth with the lens, we can determine not only the existence of ametropia but also its nature, and moreover gain an approximate idea as to its degree.

To determine this latter, however, with any exactness, it is far better as well as simpler to go at once to the upright image, which, in the comprehensiveness and delicacy of the test mentioned in the light streak of the vessels, amply fulfils all requirements either theoretical or practical. By this means the determination of astigmatism of any form or degree becomes almost as simple as that of regular refraction.

THE AMOUNT OF ENLARGEMENT PRODUCED BY THE UPRIGHT IMAGE.

Looking through the lenticular system of the eye at an object beyond, say the optic nerve, is precisely like looking through any lens of an equivalent power. The object thus seen appears enlarged, and the question is to determine in case of the eye, how great this enlargement is.

Since the relative size of the images of the same object on the retina are to each other as the respective distances of the object in front of the eye, that is in front of the nodal point, all that is needed to determine the comparative size of the image on the retina is to know the distances at which the object is seen. If, for example, a given object is at 8 inches from our nodal point it will produce an image on our retina of a certain size. If moved to 2 inches, and it is assumed that through the accommodation the object remains clear, then the size of the image of the object at 2 inches will be to that when it is at 8, as $8 : 2 = 4$. The image in the last case will be four times as large.

The result would have been precisely the same if instead of our accommodation we had used $+ \frac{1}{2}$ placed close against the eye, and we had neglected the distance between the glass and our nodal point.

To get, therefore, the magnifying power of any glass when the

bject viewed is at its focal length, we have simply to divide some distance taken as a standard by the focal length of the lens used. A distance of 8 inches has been agreed upon. The magnifying power therefore of a 2 inch lens $= \frac{8}{2} = 4$, of a 1 inch lens $\frac{8}{1} = 8$, of one-half inch lens $\frac{8}{\frac{1}{2}} = 16$, and so on.

Now the focal length of the lenticular system of the eye has been calculated to be equal to 6.7 Paris lines, that is to say, the distance from the nodal point of the eye to the retina is 6.7 lines. The magnifying power of such a lens is consequently $\frac{8''}{6.7'''}$ or $\frac{96'''}{6.7'''}$, $= 14\frac{1}{3}$. The fundus of an emmetropic eye is therefore seen under an enlargement of $14\frac{1}{3}$ diameters.

Moreover, when we look through a magnifying glass, placed close to our eye, at an object say, at its focal length, we do not see the object itself but its virtual image, and this image becomes, so to speak, for the time being, a defined picture, which the observer can project to any distance, finite or infinite, that he pleases. The greater the distance to which the image is projected, the greater the space which it appears to cover. Just as a small scotoma in one's eye may appear, when projected upon a piece of white paper held near the eye, to cover only a small circumference, but yet seem, when projected against the neighboring wall, to occupy a large extent of surface. This is due, of course, merely to the increased opening of the visual angle.

This may be illustrated in a very simple way, by imitating the condit'on of a normal eye. Set, for example, a one-inch lens so that it shall be just one inch from a piece of card on which some object—as a picture of the fundus, for instance—has been drawn. This is a rough but sufficiently exact imitation of the eye.[1] If we now place the model of the eye close to our own eye, we see an enlarged image of the picture beyond, which, by keeping the other eye open, can be projected to any distance we see fit. So,

[1] I might say here that a very convenient representation of the emmetropic eye can be had ready-made, in what is known in the shops as a cotton or linen counter. This consists of a small upright bit of brass, in which is set an inch lens of about half an inch in diameter. This upright is connected with a second upright by a short horizontal bottom piece which is just the focal length of the glass. To the second upright can be attached a bit of card with the picture of the fundus of the eye drawn upon it.

too, with the real eye as well as with the model, the optic nerve being thrown up against the opposite wall, and to all appearances covering a wide extent of surface.

If we vary the experiment a little, and draw, instead of the fundus, a square, each side of which is a determined length, say one line, and then rule a sheet of paper with squares of the same dimensions, we can then have ocular proof of the amount of enlargement. To do this we have simply to hold the model as close to our eye as possible, and then to hold the sheet of paper previously ruled into squares at exactly eight inches, since this distance is taken for the standard. If now the experiment is correctly performed, and the different measurements are likewise correct, we shall see, by keeping both eyes open, that the single square seen by one eye, and projected against the paper seen by the other, covers eight squares in each direction. Thus, the square seen with the glass forms on the retina the same size image as eight squares do without the glass. The magnifying power of the glass, therefore, is eightfold. By moving the paper away from us we see that the single square, seen through the glass, covers always an increasing, while if toward us, a decreasing number of squares.

We have seen that with the emmetropic eye the enlargement is $14\frac{1}{3}$ times, and it remains to be seen how this is influenced by a condition of ametropia.

Let $H\ \frac{1}{3}$ be present due to the shortening of the antero-posterior axis. A convex $\frac{1}{3}$ placed close against the cornea—the distance between the nodal points being neglected—will, for all practical purposes, reduce the eye to a condition of emmetropia, as rays leaving it would be parallel; yet the lenticular power, at the focal distance of which is the retina, in each case, is very different from that of the naturally emmetropic eye, for whereas in the latter it is equal to 6.7 lines, in the reduced hypermetropic eye it is greater by the lens which we have added, and equals $\frac{1}{6.7'''} + \frac{1}{3''}$, or reducing this last to lines, $\frac{1}{6.7} + \frac{1}{36} = \frac{1}{5.6}$. We have, consequently as the enlargement $8''$ or $96'''$ divided by $5.6'''$. $\frac{96}{5.6} = 17.\frac{1}{7}$ times.

It would have been the same had H been latent and corrected by the accommodation.

Suppose $M\,\frac{1}{3}$ is present, caused by lengthening of the axis. It would require $-\frac{1}{3}$ close to the cornea to make the rays leave the eye as parallel. The lenticular system, at the focal distance of which the retina is, would then be equal to $\frac{1}{6.7'''}-\frac{1}{3.6'''}=\frac{1}{8\frac{1}{4}}$. $\frac{96}{8.25}=$ $11.\frac{1}{2}$.

If in any case it could possibly happen that with a normal length of axis there was a faulty condition of refractive power—an increase on the one hand producing M, and on the other a decrease causing H—then the lens which restored the balance would simply reduce the eye to an emmetropic eye, and we should have the same enlargement as in the normal eye.

Now, although all this is exceedingly simple in theory, it is by no means so when we come to apply it in a practical manner and to the wants of the ophthalmoscope. For the correcting glass cannot be applied directly against the cornea, neither can the distance between the nodal points be neglected. Nor can we assume, as we have done, that the anatomical conditions are the same in all eyes to such a degree that the component parts of the fundus—as, for example, the optic disk and vessels—are invariably the same size. Indeed, we are certain that here, as elsewhere in the body, they vary to a considerable amount. This would be naturally expected, and would be in accordance with the fact that considerable variations occur in the size of the image in eyes which are known to be emmetropic.

Manthner is inclined to believe that this difference in size of the image in a normal eye may be due to a difference in the length of the antero-posterior axis, which is counterbalanced by a corresponding increase or decrease in the refracting apparatus of the eye, by which the rays still issue as parallel. Thus we might have a longer axis with a weaker, or a shorter axis with a stronger lenticular power. The eye would, in each case, be emmetropic, but the enlargement would be greater in the latter than in the former case, and in proportion to the degree of shortening.

Manthner has calculated that while the enlargement in $H=\frac{1}{3}$ is $17\frac{1}{2}$ times, the glass being considered an integral part of the eye, it is in the same degree of H corrected by $+\,3\frac{1}{2}$, half an inch from the nodal point, but $15\frac{1}{2}$ times; and again, if corrected

by + $\frac{1}{4}$ one inch in front of the nodal point it is only $13\frac{1}{2}$ times.

From a series of mathematical deductions the same author arrives at the following general conclusions. When an anomaly in refraction is corrected by the proper glass one inch from the nodal point, we obtain with *M* always a greater, and with *H* always a less, enlargement than with emmetropia, while with the inverted image the enlargement is less with *M* and greater with *H* than with *E.*

As it is out of the scope of this practical work to follow this and similar subjects in all their intricacies, I would refer those who have the inclination and time for the study of such details to the admirable work of Mauthner,[1] and to the essay on the same subject by Stammeshaus[2] in Zehender's Journal.

The examination of a myopic eye with a concave glass, which is necessarily stronger than the degree of the myopia, since the glass cannot be placed at the nodal point, is on the principle of the Galilean telescope, in which the lenticular system of the eye is the object-glass, and the lens behind the mirror the eye-piece. In such a combination the stronger the eye-piece the greater the magnifying power, but the farther the eye-piece must be from the eye.

If, for example, we have a myopia of $\frac{1}{6}$, the fundus can be seen, *A* being relaxed—either through $-\frac{1}{5}$ at one inch, or $-\frac{1}{4}$ at two, or $-\frac{1}{2}$ at four inches from the nodal point of the observed eye. In each case the fundus will be seen under an increasing enlargement, but at the same time with a rapidly decreasing field of view.

Stammeshaus,[3] taking advantage of this principle, proposed to reduce such eyes as were not naturally myopic to that condition by convex glasses, and then to view the fundus through concave glasses of different strengths and increasing distances in front of the eye, according to the amount of enlargement desired. This method, which had already been tried in this country several years before the suggestion of Stammeshaus appeared in print, possesses theoretical rather than any practical merits, of which,

[1] Mauthner, Lehrbuch der Ophth., ab. 1, p. 177.

[2] Zehender, Klin. Monatsblätt., Jan., 1874, p. 1.

[3] Loc. cit.

indeed, it is signally wanting. Not only on account of the great reduction of the field, but also from distortion of the image and from annoying reflections which arise from both surfaces of the interposed convex glass. When, however, the myopia is natural, and the pupil fully dilated with atropine, the method may be occasionally used with advantage, though even here it is better to go at once to the inverted image, using a weak-object lens in the manner suggested by Liebreich, and already described in the chapter on the use of the inverted image.

BIBLIOGRAPHY.

1851 Helmholtz.—Beschreibung eines Augenspiegels.

1856 Jæger, Ed.—Oesterr.—Zeitschrift für praktische Heilkunde. (No. 10, März, 1856.)

1861 Jæger.—Einst. d. dioptr. Apparates.

1861 Knapp.—Ophth. Congress. Heidelberg.

1861 Stellwag.—Lehrbuch der praktischen Augenheilkunde. Wien, Braumuller, s. 623.

1863 Schweigger.—Archiv für Ophth. Band IX., ab. 1., p. 178.

1864 Donders.—Accom. and Refrac. of the Eye, p. 351–490.

1864 Schweigger.—Vorlesungen ueber den Gebrauch des Augenspiegels. Taf. 1, figs. 1–2.

1867 Mauthner.—Lehrbuch der Ophthalmoscopie.

1867 Helmholtz.—Handbuch der Phys. Optik.

1867 Javal.—Javal. Études ophthal. (Wecker). Tom. II., fasc. 2, p. 836.

1869 Loring, E. G.—Amer. Ophth. Soc. Trans. July.

1869 Teulon, G.—Ann. d. Oculistique. Sept., 1869, p. 95.

1870 Loring, E. G.—Amer. Journal of Medical Sciences. April.

1870 Knapp.—Archiv. Ophth. et Otol. Vol. 1., No. 2, p. 397.

1871 Schweigger.—Handbuch der speciellen Augenheilkunde.

1872 Couper.—Report Fourth Inter. Ophth. Congress. London, p. 109.

1873 Knapp.—Trans. Amer. Ophth. Soc. July.

1874 Knapp.—Archiv. Ophth. et Otol. Vol. II., No. 2.–Vol. IV., No. 1.

1874 Loring.—American Journal of Medical Sciences. Jan.

1874 Knapp.—New York Medical Record. Jan. 15th.

1874 Loring.—New York Medical Record. March 2d.

1874 Stammeshaus.—Klin. Monatsblätter. Zehender. Jan.

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